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BIOGRAPHICAL MEMOIRS

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PREFACE.

In accordance with a rule of the National Academy of Sciences, it is the duty of the President, upon the death of a member, to select some one to prepare a biographical memoir of the deceased.

Such memoirs have been collected in permanent form from time to time for the use of the Academy and for distribution among reference libraries in this country and in Europe. Each biography is supplemented by a list of the more important publications of the deceased member, and is accompanied by a likeness and a facsimile of his signature.

The present is the seventh volume of the series and contains fourteen memoirs. It should be stated that all of these memoirs here brought together in book form have been issued separately.

With the close of this volume and at the end of the first half century since the organization of the Academy, one hundred and eight biographies have been published.

ARNOLD HAGUE,
Home Secretary.

WASHINGTON, April 15, 1913.

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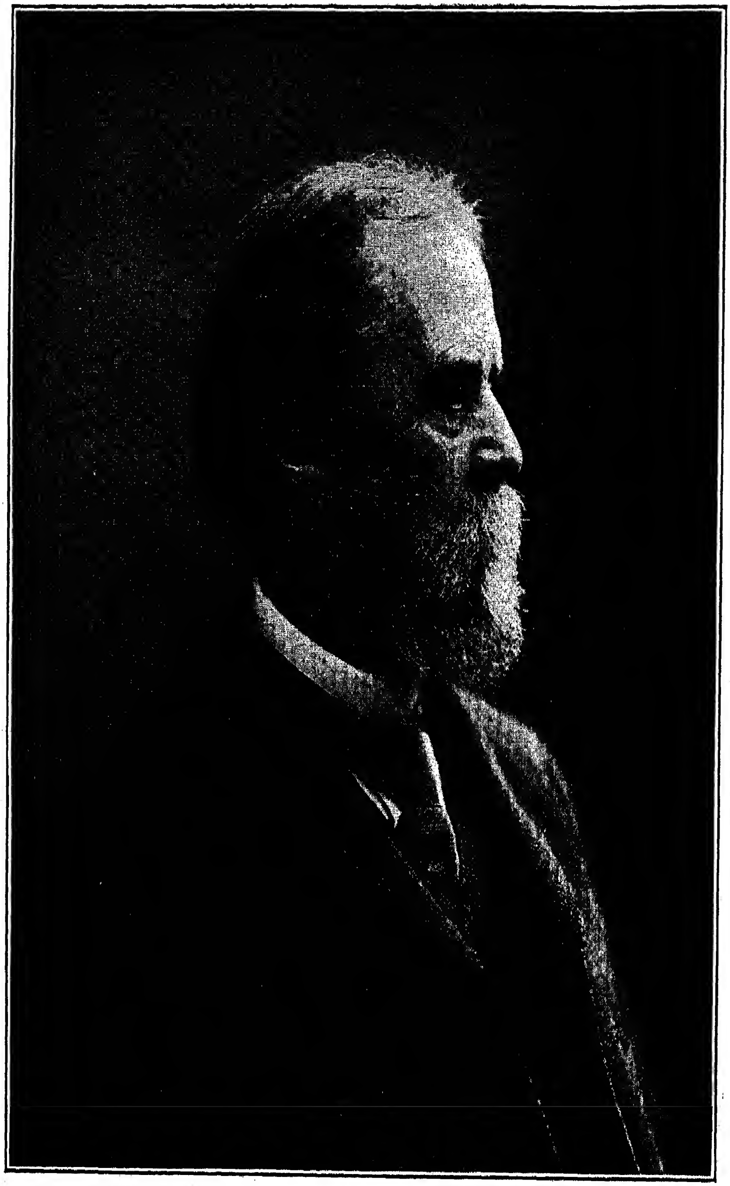

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Wolcott Gibbs

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VII

BIOGRAPHICAL MEMOIR

OF

WOLCOTT GIBBS

1822-1908

BY

F. W. CLARKE

CITY OF WASHINGTON
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WOLCOTT GIBBS.*

Oliver Wolcott Gibbs,† a charter member of the National Academy of Sciences, and at one time its president, was born in the city of New York, February 21, 1822. His father, Colonel George Gibbs, was a man of some wealth, who owned a large country place at Sunswick, on Long Island, not far from the then small metropolis. He was an enthusiastic mineralogist, and gathered a collection which, ultimately sold to Yale College, became the nucleus of the great cabinet since made famous by the labors of the two Danas, Brush, and Penfield. It was perhaps the control of the Gibbs collection which first led J. D. Dana to write his classical "System of Mineralogy." Colonel Gibbs, for whom the mineral *gibbsite* was named, was himself the author of several memoirs upon mineralogical subjects; and his oldest son, also named George, achieved some reputation as a geologist and as a student of ethnology. Wolcott Gibbs was born into an atmosphere of scientific interests, and his early associations must have influenced his choice of a career. A taste for science ran in the family.

Laura Gibbs, the mother of Wolcott, came of distinguished ancestry. Her father, Oliver Wolcott, rose through various positions to that of Secretary of the United States Treasury; a post which he held during the latter part of Washington's administration and well into the administration following. He then became a justice of the United States Circuit Court, and during the last ten years of his life he was Governor of the State of Connecticut. His father, another Oliver, was a magistrate, a major general of militia, a member of Congress, and a signer of the American Declaration of Independence. He too was a Governor of Connecticut, and so also was his father, Roger Wolcott, the first noteworthy member of the line. In

* Read before the National Academy of Sciences, November, 1909.

† He dropped the Oliver early in his career.

short, the ancestors of Wolcott Gibbs were people of far more than average ability, who had the confidence and esteem of their fellow-citizens, and were therefore entrusted with positions of high rank and responsibility. Even though there was no commanding genius among them, no man of world-wide fame, they at least left to their descendants a legacy of lofty examples, well worthy of emulation. We may differ in our opinions as to the significance of heredity; but we can recognize the fact that Gibbs received from his forbears a sound mind in a sound body, together with traditions of well doing that could not be disregarded. A good ancestry is a good beginning for any man

In his early environment Gibbs was also fortunate. Although he was only eleven years old when he lost his father, his mother survived for many years, and gave him the best of opportunities for healthy development. She was a woman of strong character and unusual ability, and her home became a center in which the best intellectual society of New York was to be found. Her character, forceful, positive, patriotic, and public spirited, was reflected in that of her son.

The early childhood of Wolcott Gibbs was largely spent at his father's estate of Sunswick, where, as he tells us in a brief autobiographical note, "he was often occupied with making volcanoes with such materials as he could obtain, and in searching the stone walls . . . for minerals, and the gardens and fields for flowers." At the age of seven he was sent to a private school in Boston, where he was under the care of a maiden aunt, whose sister had married the famous Unitarian divine, William Ellery Channing. The winters were passed in Boston, and the summers with the Channings at their country place near Newport, Rhode Island. Here again he was surrounded by choice influences, and saw many distinguished people. The reputation of Dr. Channing attracted many visitors, including more than a few from abroad, and the boy must have come to some extent in contact with them. Being but a child, he may not have understood or appreciated his opportunities, but his imagination could not have been entirely unaffected. His early associations foreshadowed his later career.

When he was twelve years old, Gibbs returned to New York, and began his preparation for college. In 1837 he entered Columbia College as a freshman, and graduated in 1841. It was in his junior year that he published his first scientific paper, a description of a new form of galvanic battery, in which carbon was used, probably for the first time, as the inactive plate. This achievement, unimportant as it may seem now, was really remarkable in two ways; first, on account of the youth of the author, and secondly, because of the conditions under which the work was done. In those days the American colleges, like the public schools of England, were intensely classical in their aims, and science received the minimum of attention. Latin, Greek, and mathematics ruled the curriculum, with only a smattering of other subjects. Even in the classics literature was subordinate to grammar, and as for the modern languages they were almost if not quite ignored. What science was taught was taught by lectures and text-book recitations, for the era of laboratory instruction had not begun. That a pupil of eighteen should make an original investigation under such conditions was surprising, but it showed the irresistible tendencies at work in his mind. The early impulses, received from his father, could not be overcome.

After receiving his bachelor's degree young Gibbs went to Philadelphia, where he served as assistant in the laboratory of Robert Hare, the well-known inventor of the compound blowpipe, who was then Professor of Chemistry in the Medical School of the University of Pennsylvania. Gibbs' purpose was to fit himself for holding a similar professorship, and so, after several months of experience with Hare, he entered the College of Physicians and Surgeons in New York, and in 1845 became a full-fledged Doctor of Medicine. He never practiced, and probably never intended to do so, for the study of chemistry was the main purpose of his life, and his medical studies were only a means to an end. Indeed, they stood him in good stead when, many years later, in collaboration with Drs. Hare and Reichert, he undertook to study the physiological effects of definitely related chemical compounds on animals.

Up to this point the training of the future chemist had been only preliminary, a laying of foundations, so to speak. In his time advanced scientific education was not easily obtained in America, and ambitious students who were able to do so sought their higher opportunities in Germany. Accordingly, Doctor Gibbs, as we must now call him, went abroad, and began by spending several months with Rammelsberg in Berlin. After this he studied for a year under Heinrich Rose, which was followed by a semester with Liebig at Giessen. He next went to Paris, where he attended lectures by Laurent, Dumas, and Regnault, and in 1848 he returned home, ready to begin the real labors of his life. Among his teachers the one who most impressed him was Rose, whom Gibbs greatly admired, and who doubtless gave his pupil his strong bias towards analytical and inorganic chemistry. From his other teachers, however, Gibbs acquired a breadth of view and an insight into different fields of research, which made him all the stronger as an investigator. He was a chemist in the largest sense of the term, and not a mere sub-specialist.

After returning to America, Gibbs first delivered a short course of lectures at Newark College, in Delaware. Then, in 1849, his native city claimed his services, and he was appointed professor of chemistry in the newly established Free Academy, now the College of the City of New York. He remained in this position for fourteen years, chiefly occupied in teaching elementary students, and at first doing, apparently, little else He was not idle by any means, but he was finding himself, and his time was not wasted. It was in 1857 that his first really notable research was given to the world, namely, the joint memoir of Gibbs and Genth on the ammonio-cobalt bases. Of this I shall speak more at length later. In 1851 he became an associate editor of the American Journal of Science, and began the preparation of a series of abstracts which brought the results of foreign investigations to the attention of American readers. These abstracts amounted in all to about 500 pages, and were, despite their brevity, conspicuously clear and comprehensive. In 1861 the first of his papers upon the platinum metals appeared, and his reputation was at last firmly established.

Notwithstanding his recognized ability, Doctor Gibbs, during this period, suffered one serious disappointment. The chair of chemistry in his *alma mater,* Columbia College, became vacant, and Gibbs, backed by the recommendations of nearly all the leading men of science in America, was a candidate for the position On very questionable grounds his candidacy was rejected, and a man of smaller attainments received the appointment. This was unfortunate for Columbia, but not altogether so for Gibbs. In 1863 he was called to a very desirable post, the Rumford Professorship in Harvard University. Nominally, this was a professorship of the "Application of Science to the Useful Arts," but its incumbent, in addition to lecturing upon heat and light, was expected to take charge of the chemical laboratory in the Lawrence Scientific School, and this gave Gibbs a great opportunity for usefulness Furthermore, the position was a delightful one upon its social side, and he was thrown into close association with many congenial spirits. There were Louis Agassiz the zoologist, Asa Gray the botanist, Jeffries Wyman in comparative anatomy, Benjamin Pierce in mathematics, and J. P. Cooke in chemistry. Literature was represented by Longfellow, Lowell, Holmes, and other less famous writers; altogether an aggregation of distinguished men which could not be matched elsewhere in America and equalled at few places in the world. Gibbs was among his peers, and in a place where his worth could be fully appreciated.

Doctor Gibbs remained in charge of the Scientific School laboratory for eight years, and during that time his researches were for the great part, although not exclusively, devoted to analytical methods. The school was technically a department of Harvard University, and yet its work was carried on quite independently. The students were usually men of definite purposes, who knew what they wanted and went where it could be best obtained. They went to Agassiz for zoology, to Gray for botany, and to Gibbs for chemistry, because those men were the leaders in their respective subjects, and they worked, not in classes, but as individuals. The students in chemistry had little or nothing to do with the students in other branches, for the school was distinctly professional in its aims. Teachers

from other institutions, seeking to enlarge their knowledge, were often among them. Gibbs was now training men who intended to become chemists, and some of them were qualified to assist in his investigations Moreover, he was not overloaded by numbers, for he rarely had more than twenty students in attendance at any one time. There was one assistant, to relieve him of routine work; his lectures upon light and heat cost him little effort, and he was therefore able to devote his energies to research more advantageously than ever before.

It was my good fortune to have been a student under Gibbs during the greater part of four years, between 1865 and 1870 I may therefore be permitted to speak of his teaching from my own experience, believing that in such matters the personal note is not without value. There was nothing unusual about the course of instruction so far as ordinary details went, for that necessarily followed certain well established lines Most of the students had already gained some elementary knowledge of chemistry; their work began with the usual practice in analytical methods and chemical manipulations, and as the men showed capacity they were admitted to the confidence of their master and aided him in his investigations. This procedure may seem commonplace enough today, but in the years of which I speak it was new to American institutions, and was looked upon doubtfully by some of the old-fashioned pedagogues. The students who chose to do so attended the chemical lectures of Cooke in Harvard College, but that work was wholly optional The only formal examination was the final examination for the bachelor's degree, and therefore there was little or no cramming. Gibbs apparently believed, although his belief was not stated in set terms, that a good teacher who kept in touch with his pupils should know perfectly well where they stood, and no examination could tell him anything more. In fact, examinations are often misleading, for the reason that even a fine scholar of nervous temperament may become confused and helpless during the ordeal, and fail to answer the simplest questions. On the other hand a poor student with a fair memory may cram for an examination, pass triumphantly, and amount to nothing afterwards. The real examinations under Gibbs were daily interviews, when he visited each stu-

dent at his laboratory table and questioned him about his work. This, together with the reported analyses, gave the teacher a clear conception of the true standing of each man. The fewness of the pupils was a distinct advantage, for all worked together in one room, beginners and research students often side by side. The result was that they learned much from one another, and there were many discussions among them over the burning problems of the day. The men were taught to stand on their own feet, and to think for themselves, laying thereby a foundation for professional success which was pretty substantial. The course of instruction had no definite term of years prescribed for it, and graduation came whenever the individual had done the required amount of work and submitted an acceptable original thesis. The final examination was usually oral, each man alone with his master, and was conducted in an easy conversational way which tended to establish the confidence of the candidate from the very beginning. In my own case, I remember that the questions covered a fairly broad range of chemical topics, and at the end of it Doctor Gibbs drew me into a sort of discussion or argument with him over the then modern doctrine of valency. I now see that his purpose was not merely to ascertain what I had read on the subject, but what I really thought about it, if indeed I was entitled to think at all. Gibbs invariably treated his students, not as so many vessels into which knowledge was to be poured, but as reasonable beings, with definite purposes, to whom his help must be given. That help was never denied to any man who showed himself at all worthy of it. The research work in which the advanced students shared, and for which they received public credit, served to teach them that chemistry was a living and growing subject, and to train them in the art of solving unsolved problems. They were taught to *do,* and encouraged to *think,* and if, on going forth into the world, they sometimes felt themselves qualified to revolutionize all science, their vanity did no harm and was soon remedied. An enlightened ignorance is only gained with advancing years, and the enthusiastic beginner cannot be expected to appreciate it. It is the last polish that the ripened scholar acquires.

What now is the meaning of this long disquisition upon the

methods of Gibbs Laboratory? What was there at all unusual in his teaching? Nothing, perhaps, from a modern point of view, but much that was new to America in the middle sixties It was Gibbs' peculiar merit that he, more than any other one man, introduced into the United States the German conception of research as a means of chemical instruction, a conception which is now taken as a matter of course without thought of its origin Gibbs worked with small resources and no help from outside; he was a reformer who never preached reform; his students rarely suspected that they were doing anything out of the ordinary; but they had the utmost confidence in their master, and took it for granted that his methods were sound. There was nothing of the drill master about Gibbs, no trace of pedantry, no ostentation of profound learning; but the students never doubted his sincerity of purpose and interest in their work, or questioned his ability as a teacher. As for Gibbs himself, it is doubtful whether he ever imagined that his teaching was at all remarkable. He did what was to him the natural and obvious thing to do, simply and without pretense, and the results justified his policy. The success of his students is perhaps the best monument to his memory.

In 1871 the chemical instruction at Harvard University was reorganized, in spite of strong protests from Gibbs and other scientific leaders. The laboratory of the Scientific School was consolidated with that of the College, and Gibbs had no more students in chemistry. His work was limited to that of the Rumford professorship—a change which left him more time for personal research, but took from the students the inspiration of his teaching. The change may have been justifiable on grounds of economy, but it was otherwise a mistake, and it was so recognized among chemists generally. The economy was only financial; but an important asset of the University, the ability of a great teacher, was not turned to the best account. Fortunately for Gibbs he had independent means, although he was not a rich man, and he was able to equip a small laboratory of his own and to employ a private assistant. In that laboratory he carried out those brilliant researches upon the complex inorganic acids, which marked the culmination of his

career The equipment was most modest, and in some respects it reminded one of the famous kitchen of Berzelius. Indeed, Gibbs' favorite piece of apparatus was that homely utensil, a cast iron cooking stove, which served for several useful purposes. Precipitates could be dried in the oven, crucibles were buried in the coals, water was kept hot on top of it. As an instrument of research it was neither elegant nor orthodox, but it did the work, and what more could be desired? Gibbs adapted himself to circumstances, and cared little for the instrumental refinements which so many chemists seem to regard as necessary. The real essentials were provided, mere conveniences, the luxuries of research, he could do without.

For sixteen years after the closing of the Scientific School laboratory, Doctor Gibbs lectured to small classes of students upon the spectroscope and on thermodynamics In 1887 he retired, as Professor Emeritus, and went to live in his house at Newport, where he had been accustomed to spend his summer vacations. His private laboratory was moved to Newport also, and there he continued his investigations until, enfeebled by old age, he was obliged to rest on his laurels. As a recreation he cultivated a flower garden, and was proudest of his roses. In that way his love of the beautiful found its chief expression. On December 9, 1908, he passed away, at the age of nearly 87. His wife, whose maiden name was Josephine Mauran, and whom he had married in 1853, died several years earlier, leaving no children.

So much for biography. It now remains for us to consider the contributions of Gibbs to science, and to trace their relations, so far as may be practicable, to later work. An investigation never stands alone; each one touches other investigations at several points; and its worth may be greatest as the progenitor of other researches. The suggestiveness of a discovery, its influence in stimulating thought, is fully as important as its immediate outcome. It is a seed, whose value is finally determined by its fertility.

Gibbs' first paper, a "Description of a new form of magneto-electric machine, and an account of a carbon battery of considerable energy," published when he was a junior student at Columbia, has already been mentioned. In 1844 he attempted

to discuss the theory of compound salt radicles, and in 1847, while a student abroad, he published a number of mineral analyses. In 1850 Gibbs pointed out the interesting fact that compounds which change color when heated, do so in the direction of the red end of the spectrum In 1852 he published the first of his memoirs upon analytical methods, in which he proposed the separation of manganese from zinc by means of lead peroxide; and in 1853 he prepared, and partially described, an arsenical derivative of valeric acid In all of this work there was nothing of great importance, but its varied character is suggestive. It represents the efforts of an active mind, feeling its way under unfavorable conditions, and not quite sure of its true capacities Mineral chemistry, organic chemistry, analytical chemistry, chemical theory, and physics in turn attracted his attention during this formative period of his career. It was in the great research upon the ammonio-cobalt bases that Gibbs finally found himself and forced the world to recognize his ability. His apprenticeship was ended, and his work as a master had begun.

The first of the ammonio-cobalt compounds, the oxalate of luteocobalt, was prepared by Gmelin in 1822, the very year in which Gibbs was born. It was supposed, however, to be a salt, of cobaltic acid, and several other chemists, who studied it later, shared in the same misapprehension. In 1847, Genth, then at Marburg, discovered other salts of these bases, but it was not until 1851, after his emigration to America, that he published his description of them in a rather obscure journal. Genth was the first to recognize the true character of the new compounds, and he was followed by Claudet and Fremy, the three chemists working independently of one another and almost simultaneously. Up to this point Fremy's work was the most exhaustive, but it left much to be desired.

Genth had identified the two bases since known as luteocobalt and roseocobalt In 1852 Gibbs discovered the salts of xanthocobalt, which contained, in addition to the ammonia, a nitro group It was therefore quite natural that the two chemists should join forces, and in 1856 their celebrated memoir appeared. In this memoir thirty-five salts were described, of the four bases roseocobalt, purpureocobalt, luteocobalt, and

xanthocobalt, with adequate analyses, and in eleven cases crystallographic measurements by J. D. Dana. The roseo- and purpureo-compounds were for the first time clearly discriminated, although they were supposed to be isomeric—a misconception which could hardly have been avoided at that time. There was also an elaborate theoretical discussion upon the constitution of the bases, but that also was premature. The fundamental theories of structure were yet to be developed. Blomstrand, Jorgensen, and Werner, in later years, utilized the data of Gibbs and Genth, and Werner especially made the ammonio-cobalt compounds the basis of his famous theory of the constitution of the metalamines. Gibbs and Genth laid the foundations on which later investigators have built an imposing structure

Gibbs was an experimentalist rather than a theorist, and yet he neither underrated nor avoided theory. In 1867 he published a paper upon atomicities, or valences, as they are now called, in which he developed the idea, then vaguely held by others, of residual affinities. He argued in favor of the quadrivalency of oxygen, and showed that on that supposition a molecule of water must be bivalent, and any chain of water molecules would be bivalent also. He then considered ammonia in the same way, with the two bonds of quinquivalent nitrogen unsatisfied. Ammonia, therefore, was weakly bivalent, and so, too, would be a chain of ammonia molecules. This conception he applied to the interpretation of the ammonio-cobalt bases, and so, too, did Blomstrand two years later. If we consider theories of this kind not as finalities, but as attempts to express known relations in symbolic forms, we must admit that Gibbs' conception was useful, and served well for the time being. That it has given way to other views more in harmony with modern discoveries, is not at all to the discredit of its author. In the later papers by Gibbs, published in 1875 and 1876, he made good use of his hypotheses, and described many more ammonio-cobalt compounds. Among them were the salts of an entirely new base, croceocobalt, in which two nitro-groups were present. In all, five distinct series were studied, their chlorides being represented, in modern notation, by the subjoined formulæ:

Luteocobalt chloride......	$Co(NH_3)_6Cl_3$.
Roseocobalt chloride........	$Co(NH_3)_5.H_2O.Cl_3$.
Purpureocobalt chloride......	$Co(NH_3)_5.Cl.Cl_2$.
Xanthocobalt chloride.....	$Co(NH_3)_5.NO_2.Cl_2$
Croseocobalt chloride	$Co(NH_3)_4(NO_2)_2Cl$.

Gibbs' formulæ were somewhat different from these, being doubled, and with the water of roseocobalt regarded not as constitutional, but as crystalline. The simpler, halved expressions were established by cryoscopic methods which did not exist when Gibbs conducted his investigations.

The researches upon the platinum metals, published by Gibbs in the years 1861 to 1864, relate mainly to analytical methods. Processes for the solution of iridosmine were carefully studied, and various new separations of the several metals from one another were devised. Incidentally, a number of new compounds were prepared, which, with a few exceptions, Gibbs never fully described. In 1871, however, he published a brief note on the remarkable complex nitrites formed by iridium,* and in 1881 he described a new base, osmyl-ditetramin, $OsO_2.4NH_3$, together with several of its salts. These researches were never pushed very far, and were discontinued for lack of proper facilities. They were, nevertheless, distinct additions to our knowledge of the platinum group.

I have already mentioned the work done by Gibbs and his students in the Laboratory of the Lawrence Scientific School. This covered a wide range, partly in developing and perfecting old analytical methods, partly in devising new ones. There were improvements in gas analysis, especially in the determination of nitrogen, and a great variety of analytical separations. I will not attempt to give a catalogue of these investigations, but will limit myself to a few of the more noteworthy. A new volumetric method for analyzing the salts of heavy metals was worked out, in which a metal such as copper or lead was precipitated as sulphide, the acid being afterwards determined by titration. The estimation of manganese as pyrophosphate was another of these contributions to analysis. But the most important of all was the electrolytic determination of copper, now

* Ber. Deutsch. chem. Ges., 4, 280. Not a separate paper, but part of his correspondence.

universally used, which was first published from Gibbs' laboratory. It is true that a German chemist, Luckow, claimed to have used the method much earlier, but so far as I can discover he failed to publish it. Gibbs, therefore, is entitled to full credit for a process which was the progenitor of many others. The entire field of electro-chemical analysis was thrown open by him, and it has been most profitably cultivated.* Gibbs also, during this period of his activity, invented several instrumental devices of great convenience. The ring burner, and the use of porous septa when precipitates are to be heated in gases, are due to him. Furthermore, in cooperation with E. R. Taylor, he devised a glass and sand filter which was the forerunner of the porous cones invented by Munroe when the latter was a student in Gibbs laboratory. That, in turn, preceded the well-known perforated crucibles of Gooch, who was one of Gibbs' assistants. The genealogy of these inventions is perfectly clear.

We come now to the remarkable series of researches upon the complex inorganic acids, which Gibbs began to publish in 1877, and continued well into the nineties. The ground had already been broken by others; silicotungstates, phosphotungstates, phosphomolybdates, etc., were fairly well known, but they were commonly regarded as exceptional compounds rather than as representatives of a very general class. In his first preliminary communication upon the subject Gibbs indicated the vastness of the field to be explored, and showed that the formation of complex acids was characteristic of tungsten and molybdenum to an extraordinary degree. The phenomena were general, not special; and no limit could be assigned to the possible number of acids which these elements might form.

In his systematic work, following his preliminary announcement, Gibbs first revised the sodium tungstates in order to determine their true composition. Then, after preparing a number of phosphotungstates and phosphomolybdates, he studied the corresponding compounds containing arsenic in place of phosphorus. He next obtained similar vanadium compounds, and also showed that the phosphoric oxide of the first known

*Notably by Smith in this country, and Classen in Germany.

acids was replaceable by phosphorous and hypophosphorous groups. Later still, he replaced the normal phosphates by pyro- and meta-phosphates, and also prepared complex salts containing arsenious, antimonious, and antimonic radicles. Stanno-phosphotungstates and molybdates, platinotungstates, and complex acids containing mixed groups were discovered, together with analogous compounds of selenium, tellurium, cerium, and uranium One salt described, a phospho-vanadio-vanadico-tungstate of barium, had the formula

$$60\ WO_3\ 3P_2O_5\ V_2O_5\ VO_2\ 18BaO.150H_2O,$$

with a molecular weight of 20066. Compared with this substance the supposed complexity of most organic compounds becomes simplicity itself, and their interpretation seems relatively like child's play. In all, Gibbs described complex salts belonging to more than fifty distinct series, and did his work in a small private laboratory, with only a single assistant. With greater resources at his command, what might he not have accomplished?

In 1898, in his address as retiring president of the American Association for the Advancement of Science, Gibbs summed up his views as to the constitution of the complex acids. His presentation of the subject, however, can hardly be regarded as final. The problems involved are too complicated to be easily solved, and much future investigation is needed in order to determine the true character of these extraordinary substances. Gibbs was a pioneer, breaking pathways into a tangled wilderness; but the ways are now open, and he who wills may follow. Possibly some of the compounds so far obtained were double salts; others may have been isomorphous mixtures; and in some instances phenomena of solid solution perhaps obscured the truth. By physical methods, cryoscopic or ebullioscopic, the molecular weights of the salts must be determined; their ionization needs to be studied, and in such ways their true nature can be ascertained. These methods of research have been mainly developed since the work of Gibbs was done; he therefore cannot be criticised for not employing them. Since his time chemists have come to recognize many compounds as salts containing complex ions, such as, for example, the oxalates, tartrates, etc., of iron, aluminum, chromium, and anti-

mony, with other bases of lower valency. Even many of the silicates are easiest to interpret as salts of alumino-silicic acids, although the physical proof of their nature is difficult to obtain. The constitution of the complex acids is one of the great outstanding problems of inorganic chemistry.

Although he was distinctively an inorganic chemist, Gibbs did not entirely neglect organic chemistry. In 1868 he discussed the constitution of uric acid and its derivatives, and in 1869 he described some products formed by the action of alkaline nitrites upon them. He also produced several memoirs upon optical subjects, such as one upon a normal map of the solar spectrum, and another upon the wave lengths of the elementary spectral lines. Again, he devoted some time to the study of interference phenomena, and discovered a constant, which he called the interferential constant, that was independent of temperature. One of Gibbs' latest papers, published when he was seventy-one years old, related to that extremely difficult subject, the separation of the rare earths—a subject in which he had always taken a deep interest. In this paper he developed a new method for determining the atomic weights of the rare-earth metals, which was based upon analyses of their oxalates. The oxalic acid was determined by titration with permanganate solutions, and the oxides by ignition of the salts. From the ratios between the oxalic acid and the oxides the molecular weights of the latter could be computed without reference to the amount of moisture in the initial substances. This method has since been employed by others, and especially by Brauner, in his work on the atomic weights of cerium and lanthanum. It is worth noting here that Gibbs had previously taken some part in atomic weight determinations. Those of Wing on cerium, and of Lee on cobalt and nickel, were made in Gibbs' laboratory and under his guidance. Furthermore, Gibbs was one of the earliest American chemists, if not the first, to accept the modern or Cannizzaro system of atomic weights, and to use it in his teaching. His mind was never closed to new ideas. It welcomed light from all sources.

Gibbs wrote no books and delivered no popular lectures. He was therefore little known to the public at large, but within scientific circles he received high honors. He was president of the National Academy of Sciences from 1895 to 1900, and he

also presided over the American Association for the Advancement of Science in 1897. Honorary membership in the German, English, and American chemical societies, and in the Prussian Academy was conferred upon him, and he received honorary degrees from several universities. His life was that of a devoted scholar, caring most for research, and indifferent to popularity. Sensationalism and self-advertising were most obnoxious to him; indeed, in these respects, no man could have been more fastidious. The approval of his fellows he fully appreciated, but only when it was spontaneous and deserved. It must not be inferred from these remarks that Gibbs was deficient in public spirit, for that would be most untrue. During the Civil War, from 1861 to 1865, he was strongly patriotic, and did much to help the Union side. The Union League Club of New York, organized to bring together the more patriotic citizens of that city, was founded at a meeting in his house, and is today a strong social institution. Gibbs was also active in the Sanitary Commission, an organization modeled upon the work of Florence Nightingale in the Crimea, and the forerunner of the Red Cross Society of today.

Wolcott Gibbs was a man of striking personality, tall, erect, and dignified. As with most men of positive character, he had strong likes and dislikes, but the latter never assumed unworthy form. To his friends he was warmly devoted, and always ready to help them in their work with manifold suggestions. His breadth of mind is indicated by the range of his researches, and his liberality by the way in which he encouraged his students to develop his ideas. More than one important investigation was based upon hints received from him, and was carried out under his supervision, to appear later under another name. Gibbs never absorbed the credit due even in part to others, nor failed to recognize the merits of his assistants in the fullest way. Had he been more selfish, his list of publications would have lengthened, but his sense of justice was most keen, and therefore he held the esteem and confidence of his co-workers. No man, not even among his opponents, for such there were, could ever accuse him of unfairness. He deserved all honor, and his name will live long in the history of that science to which his life was given.

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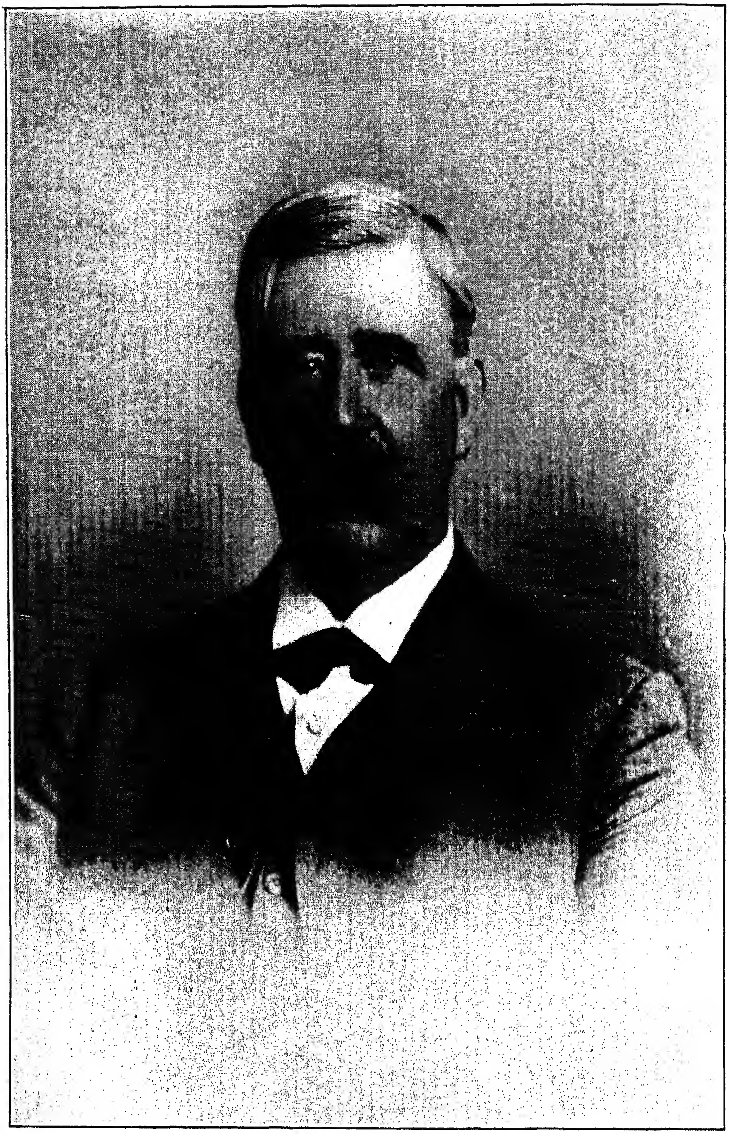

Yours Truly
W. K. Brooks

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WILLIAM KEITH BROOKS.*

ANCESTRY AND FAMILY.

William Keith Brooks, Professor of Zoology in the Johns Hopkins University, was born at Cleveland, Ohio, March 25, 1848, and died at his country home, "Brightside," near Baltimore, November 12, 1908.

Although Professor Brooks used to say jocosely that his known line of descent was too short to be of much interest to a student of phylogeny, it goes back, nevertheless, to some of the earliest settlers of Massachusetts. On his father's side he was descended from Thomas Brooks, who came from England to Boston prior to 1634, and soon thereafter settled in Concord For five generations preceding the Revolution the Brooks homestead was in Concord His great grandfather, Joshua Brooks, served in the battle of Concord; his grandfather, Joshua Brooks, was born in Lincoln, Massachusetts, in 1780, whence he removed to Burlington, Vermont; his father, Oliver Allen Brooks, was born in Middlebury, Vermont, in 1814, and moved to Cleveland, Ohio, in 1835, where he became one of the early merchants of that city.

Through his mother he was descended from John Kingsley, who came from England to Dorchester, Massachusetts, about 1638. His maternal grandfather, the Rev. Phineas Kingsley, was born in Rutland, Vermont, in 1788, and moved to Ohio in 1847; his mother, Ellenora Bradbury Kingsley, born June 30, 1817, was married in 1840 to Oliver Allen Brooks, of Cleveland. The parents of Professor Brooks were second cousins,

* In the preparation of this memoir the writer has had the invaluable assistance of Mr Oliver K Brooks and Prof E A Andrews. The former has supplied all information available concerning the ancestry and early life of his brother, and he has also furnished certain details concerning his later life and personal traits Professor Andrews has assisted materially in the compilation of the bibliography, and a free use has been made of his several articles on Professor Brooks.

both of his grandmothers having been cousins of the name of Keith, and descended from the Rev. James Keith, who came from Scotland to Boston in 1662, and became the first settled minister of Bridgewater, Massachusetts.

Although the genealogy of Professor Brooks is thus known for eight generations, the characteristics of his ancestors are not sufficiently well known to justify an attempt to study his heredity. Most of his immediate ancestors in this country were farmers, but his maternal grandfather, the Rev. Phineas Kingsley, was a Congregational clergyman. He had only a common-school education, and had studied theology under a local clergyman, but he was a studious, well-informed man, he had a fund of knowledge about animals and plants, derived from his own observations, rather than from reading, and it is not improbable that his conversation and example may have turned his grandson's attention to the study of living things.*

William Keith Brooks, the subject of this memoir, was the second son of Oliver Allen and Ellenora (Kingsley) Brooks He had three brothers, all of whom survive him; the oldest, Oliver Kingsley Brooks, born May 21, 1845; the third son, Charles Ernest Brooks, born March 30, 1851; the youngest, Edward Howard Brooks, born November 21, 1854.

Professor Brooks married, on June 13, 1878, Amelia Katherine Schultz, daughter of Edward Thomas Schultz and Susan Rebecca (Martin) Schultz, of Baltimore. To them two children were born, Charles Edward Brooks, August 26, 1879, and Manetta White Brooks, April 21, 1881; the former, after finishing his undergraduate course, took the degree of Ph. D. in mathematics at the Johns Hopkins University, and is now devoting himself to research in that subject; the latter is a graduate of Vassar College, and after the death of her mother in 1901, took charge of her father's home and became his daily companion; in 1909 she married J Frank Daniel, Bruce Fellow in Biology in the Johns Hopkins University.

Professor Brooks rarely spoke of his ancestry or early life, and for the following illuminating account of his boyhood,

* William L Kingsley, long-time Treasurer of Yale College, was a cousin of Phineas Kingsley

which I have taken the liberty of editing and arranging, I am indebted to his brother, Oliver K. Brooks.

EARLY HISTORY OF W K BROOKS

By Oliver K Brooks

EARLY DAYS IN CLEVELAND

"The conditions in which my three brothers and I spent our childhood and youth were almost ideal. Our father lived on lower Euclid avenue, then one of the pleasantest and most agreeable residence sections of the city, now entirely given up to business. We had congenial neighbors, most of whom lived near us for a long time. Many of them had children of about our own ages who were our friends and companions

"We lived in a large, comfortable, and substantial old frame house with large grounds, especially in the rear, where there was an apple and pear orchard and a hickory tree, reminders of the time when the place was country property, or perhaps part of a farm.

"Near the house was a builders' lumber yard, which was a favorite playground for us, and near by, in another direction, was a convent of Ursuline nuns, with extensive buildings and grounds, separated from the street by a high brick wall. This convent was a place of mystery to us.

"We had an indulgent father and a devoted mother, and an aunt, my mother's sister, who lived with us as one of the family until she married, and until some time after, when her husband, Mr. Warner, bought a house nearly opposite our own. Their house was always like a second home to us.

"My mother's father and mother lived on a small farm some five or six miles south of the city on the Columbus road. He was a retired Congregational clergyman, but he never had a church of his own after he came to Ohio, but used to preach in neighboring towns when he was needed.

"It was a great delight to us to visit our grandfather's farm, and I and my brother William used to spend Saturdays and holidays there. Grandfather used to entertain us with stories of his life in Vermont and of the pioneer days there. He had seen military service in the days preceding the War of 1812.

He had an excellent memory, and was a very good story teller He taught us to fish, and used to take us on nutting expeditions in the fall.

"Talks with him may have had something to do with turning my brother's thoughts to the study of animated nature He had in his small library two books—"Thompson's History of Vermont" and the "Philosophy of Natural History," by Smellie—in both of which I know my brother was interested The first contained an account of the fauna and flora of Vermont, and served my brother as a sort of text-book. I have the book in my possession now, and in it my brother has marked the birds and other creatures which he had found about Cleveland In some cases he had indicated where the specimens were found.

"My uncle, Mr Warner, noticed my brother's taste for the study of animals, and encouraged it, and gave him a copy of "Wood's Natural History" as a Christmas present in 1862 While still a schoolboy my brother sent to a sporting paper called "Wilkes' Spirit of the Times," an interesting account of the intelligent conduct of a little dog which belonged to his grandfather. The account, I believe, was headed "Do Animals Reason," and was in the form of a letter to the paper, and was either not signed or only signed with initials. Our uncle discovered it in the paper, and guessed that it was written by my brother, and he "owned up" on being spoken to about it I think this was his first appearance in print.

"One of our neighbors was the geologist, Prof J S Newberry, afterwards of the School of Mines, Columbia College He had several sons who were companions and playmates of my brother, and I think they used to go on excursions into the country and collect specimens together. Doctor Newberry had, in a small building near his house, a large collection of fossils and geological specimens, and a knowledge of these may have stimulated my brother to make similar collections I remember that my brother during his school days read, with a great deal of interest, Hugh Miller's works on Geology, and the works of Doctor Buckland on the same subject, and other books of a similar nature.

"Our mother died after a very brief illness, in June, 1862. My father's mother and sister kept house for him until he married again. His second wife was a widow with a young daughter, who became a member of the family and introduced a new element of interest into our home life.

"The nearby lake, river, and canal were, of course, very attractive to young boys. There was a good bathing beach on the lake shore within walking distance of our house, and we used to go there to bathe during the summer. The river and canal abounded in fresh-water mollusks which were interesting. A part of the river, near where it emptied into the lake, had been cut off by a change of the channel, and was known as the "old river bed" Wild fowl were found there, especially in the spring and fall, and my brother once shot a blue heron there. On one of our trips to the "old river bed" my brother's dog chased some chickens. The owner, an old German, was very angry, or pretended to be, and brought out a shotgun and threatened to shoot the dog. We were thoroughly alarmed, but my brother stooped down without a moment's hesitation and put his arm around his dog and shielded him with his body. He was willing to run the risk of being shot rather than have his pet and companion exposed to danger.

"My brother became interested in aquaria, and had an aquarium in the house and a pond in the yard, stocked with tadpoles, water snails, and small fish. In this pond lived a frog which had learned to come and take flies from his hand. He always had animal pets, which he treated with great kindness; almost always a dog was his companion on his tramps, and he also had pet rabbits, cats, and squirrels. He was very skillful in training animals.

[To his students in after years Professor Brooks occasionally spoke of these early observations and experiments upon animals. In particular he recalled the great flocks of carrier pigeons which at times darkened the sky, and which flew so low after their long southward flight across Lake Erie that they could be struck with poles and clubs as they rose over the bluffs on which Cleveland stands.]

"In imitation, probably, of Professor Newberry's collection, he established a sort of museum in the upper story of the barn

back of the house, where he had a collection of shells, fossils, minerals, and geological specimens arranged on shelves, classified and labeled.

"It was probably about this time that he learned to stuff birds, or rather to prepare their skins for preservation. He may have learned to do this from some lectures given by Doctor Kirtland on the subject.

"When he grew old enough to be allowed to do so, he took long tramping expeditions into the neighboring country, sometimes hunting a little, but mostly exploring, observing, and collecting specimens. He formed a friendship with Col. Charles Whittlesey, a geologist and mineralogist, and with him explored and investigated some of the Indian mounds and earthworks in the valley of the Cuyahoga river

"In his walks and excursions his mind seemed always occupied with problems suggested by what he saw. The commonest objects which most would pass by without a moment's thought set him to thinking and trying to work out explanations of observed features, conditions, and phenomena.

"The first microscope my brother had was made for him by his friend, Mr Charles F Brush, the inventor of the Brush electric light. My brother had learned to grind glasses, and devised an ingenious method of making a holder for glass he was grinding. He cut off a piece of broomstick, wrapped paper around it, letting the paper project above the end of the stick, forming a sort of cup or socket. Into this he poured lead, and before the lead had hardened he pressed a marble into it, forming a concavity which served as a socket to hold the glass while being ground.

"Some of the work on the microscope may have been done in the office of Dr. A. Maynard, a retired physician of cultivated and scholarly tastes, who had a fine metal-working lathe which he allowed my brother to use The Doctor always took an interest in my brother's work and assisted him in many ways I do not know when my brother first made his acquaintance, but as the Doctor was a friend of my aunt and uncle, Mr. and Mrs. Warner, it was probably at their home that the acquaintance began. The Doctor had a fine library, and encouraged my brother to come to his rooms and make use of his books.

SCHOOL DAYS.

"My brother received his early education at the public schools of Cleveland. The schools he attended were all within walking distance of our home He first attended the "Prospect" School, primary and intermediate, quite near home One of his teachers, a lady, says of him "I remember him as possessing a most cheerful and loving disposition, and being very bright and quick to learn." From that school he was advanced to the "Eagle" grammar school. The principal was a Mr. Perkins, who was assisted by his wife They remember him as a good boy of quiet and gentle manners, who never gave them any trouble, but do not recall anything to indicate the ability he afterwards developed One of his schoolmates there was Prof. Theodore B. Comstock, now of Los Angeles, California, who wrote me as follows:

> William (we called him Will) was fond of animals and was of an investigating turn of mind, as a boy He knew more of Nature than his associates and took keen interest in what he observed. Reptiles and venomous insects were his pets His will was strong, but not aggressive An incident in my experience with him will illustrate this One day I had teased him, and on our way home he quietly said, "Don't you say that again" I ran off to a safe distance and mocked him He started for me with doubled fist, showing no emotion, but coming towards me with a steady walk I dodged him for awhile, and then concluded he had given up the chase, as he did not appear angry and kept up his steady walk. Finally, I came over to him unconcernedly He walked calmly by my side, raised his arm, and struck me on my shoulder. That was all, but my shoulder was very sore for many days afterwards Aside from his attachment to animals, I remember nothing in his early youth which could be regarded as clearly indicating his later career

"He was never a plodding student, his quickness of mind enabling him to grasp a subject rapidly, and when he had once done so he lost interest in its details. From the grammar school he went, in 1863, to the Central High School, which was then quite near our home. The principal there was Dr. Theodore Sterling, afterwards president of Kenyon College, and he was assisted by Professor Norton, now Professor of Chemistry at Ohio State University, at Columbus. Both remember him well. Doctor Sterling wrote me as follows in regard to him:

I remember he was fond of taking walks in the fields and woods, and collecting and putting in his pocket whatever interested him, whether shells or pebbles or plants or bugs Sometimes when I met him he would empty his pockets, showing me what he had found and get what information he could from me about whatever excited his interest This seemed to indicate that his love for natural history was very early developed.

"Professor Norton wrote:

I do not think that he studied chemistry or Virgil under me, but in all likelihood he was under me in some of his early studies, botany and natural philosophy for instance As I call him to mind, he was a quiet, studious boy, rather reserved in his manner, and not much given to the ordinary boyhood jokes and games

The last time I met him, so far as I can recollect, he was engaged in a summer school of natural philosophy in the upper floor of the High School, together with Prof. A H Tuttle, now of the University of Virginia I was much struck with the mastery he exhibited in his school and surprised at his early maturity.

"He went by the name of 'Mummy' among his schoolmates, probably because of his silent habits. At the high school his liking for and ability in mathematics and natural science was notable, and is remembered by his teachers and fellow-students, one of whom was Dr. J. H. Lowman He and Doctor Lowman took private lessons in Greek from Professor Rueger, who was a teacher of German in the high school, and thereafter this subject had a charm for him second only to that of mathematics and natural science

"Doctor Lowman remembers his early work with the microscope, and being shown the teeth of a snail and the epithelial cells of tissues, and thinks he worked with the microscope in Doctor Maynard's office

"My mother had a liking for the fine arts, and had some little native ability in drawing and coloring, although she had had no training, and very little opportunity to cultivate this natural gift. When my brother began to use the microscope, he asked me to show him how to draw the objects he was studying. I gave him a few instructions, but almost from the start he grasped the idea, and soon became very skilful in drawing with the pen. All he seemed to need was a few suggestions to start him right, and he went on without assistance and soon taught himself to make beautiful and elaborate drawings with the pen.

"He had a congenital defect of the heart which prevented his taking any active part in sports at school, but he was fond of playing checkers, and was very expert indeed at the game. A little later—perhaps he was sixteen years old at the time—he took up chess, and gave it serious thought and study. In later life he was an expert whist player, and was rarely, if ever, beaten at the game.

"He organized a society of some of his schoolmates while at the high school, and later one which met in a room in a downtown business block. This society was called "Magnus Pax," and met to read selections and discuss various subjects There were probably not more than a dozen members, all told

"He did not graduate at the high school, but left at the end of the third, or junior, year, in 1866, to enter Hobart College

"I think my father's second wife felt little sympathy with my brother's desire to devote his life to study and research. She may have influenced my father to some degree, and I have no doubt my father was deeply disappointed in not being able to induce my brother to apply himself earnestly to business

"He may have had a feeling that if he gave his sons a common school education sufficient to fit them to make their way in business, that was enough, and after that they ought to get to work and take care of themselves. He may have looked on a college education as a luxury that might render one unfit for a business career.

"Because of this feeling it was hard for him to sympathize with or encourage my brother's desire to devote himself to a life of study and research He could not comprehend how a living could be made in that way, and he felt his sons must early find a way to support themselves While he was ready and willing to assist them in getting a start in life, he probably felt unable to do more than this, and that to do more for one in supporting him while at college might be unjust to the others, or might limit his ability to help them in turn. Still, when he found my brother bent on having a college education, he gave him all the assistance he thought he could afford, and when he achieved success and had recognition, he was very proud of him.

"An old friend of Doctor Maynard, mentioned above, told me the following incident:

"The Doctor told him that my father at one time came to him in a good deal of perplexity, to ask his advice about Will, who had then been taken into his store, but who showed no interest in business and no inclination for it, but, on the contrary, seemed to have his mind occupied with other matters which had no relation to business, and of which my father could not see the use. The Doctor had seen a good deal of Will, and Will had talked with him pretty freely about the subjects and studies which attracted him, and he told my father he thought it was better to let Will follow his evident inclination for a life of study and research, believing he would never adapt himself to a business life, and would only be made unhappy by being confined to an uncongenial occupation, but that he was in no danger of becoming a mere idle loafer, and, on the contrary, had ability which would become evident if he were allowed to follow his inclinations, and that if so allowed the boy would show he had good stuff in him and a mind above the ordinary, and would probably succeed."

COLLEGE AND UNIVERSITY CAREER

He entered Hobart College, Geneva, New York, in the fall of 1866, and left at the completion of his sophomore year His cousin, the Rev. Wm J. Cleveland, of Bostonia, California, writes: "We were at Hobart College together for some time, and it may have been through my being there and urging him to come that he began his higher studies there." He remembers that he was liked by the best element among his fellow-students for his cheerful, gentlemanly bearing, coupled with a quiet but telling wit. He was not a plodding book slave, but quick of intellect and wide-awake, and he found his recreation more in mental than in physical activity. His son, Dr. Charles E. Brooks, informs me that while his father was a freshman at Hobart he won the White Essay Prize, never before taken by a freshman. That he had already begun to read and appreciate philosophy is shown by the fact that his volume on "The foundations of zoology," published in 1898, is dedicated "To Hobart College, where I learned to study and, I hope, to profit

by, but not to blindly follow, the writings of that great thinker on the principles of science, George Berkeley."

Leaving Hobart at the end of his sophomore year, he entered the junior class at Williams College in the fall of 1868. Concerning his life at Williams, Mr. T. H. Brooks, of Cleveland, a lifelong friend, but not a relative, writes:

I look back over half a century of acquaintance with Prof. William K Brooks, commencing, of course, at a very early period in our lives We played together, went to the public school here together, and later were classmates at Williams College, and were both graduated from there in 1870. I never knew him otherwise than kind, gentle, thoughtful, and studious; not demonstrative in his friendships, but thoroughly loyal and sincere. He cared nothing for marks or prizes in college, was very liable to burn the midnight oil over some subject that specially appealed to him, and then "cut" prayers and early recitations the next morning He never put himself forward to answer the questions of the class room, but when called upon always gave a good account of himself College boys, so far as my experience goes, take the problems of calculus without question and almost without understanding, but he grasped and was delighted with every proposition, and to the utter amazement of his professors and classmates, discovered a mistake in the text-book used. He was generally acknowledged to have been the most brilliant student in mathematics Williams had ever seen."

His love of the natural sciences was fostered by the Lyceum of Natural History at Williams, an active organization which at one time sent a natural history expedition across South America, and by Sanborn Tenny, botanist and zoologist, under whom he studied. But the history of his whole life indicates that he was not led into the study of zoology by teachers or environment. We may apply to him with especial force the following sentiment from his address before the Seventh International Zoological Congress (p. 34): "Most of us have, no doubt, been drawn to our specialty by the natural bent of our minds, rather than by deliberate choice. The zoologist who best deserves the name is one whose natural bent has been too strong for him, so that he has studied zoology because he could not help it." Prof. E. A. Birge, of the University of Wisconsin, was a freshman at Williams when Brooks was a senior. He remembers that Brooks had a microscope, a rare thing in those days, and that with it he showed many interesting things to his fellow-students, who frequented his room, evenings. On

one occasion he undertook to demonstrate a cross-section of a hair, and after much difficulty in trying to cut a free-hand section, he lathered and shaved a portion of his face, and then engaged the students in other things, while he waited a half hour for the hair to grow before he shaved again.

Prof. S. F. Clarke, of Williams College, one of his first students at the Johns Hopkins University, said of him in an obituary notice in the Williams Record:

> His mind was markedly of the philosophical type which appeared even in his college days, when he was known among his classmates as "the philosopher." I remember his saying that there were two things in his college course which were of special interest to him, and which also in the retrospect gave him the most satisfaction. one was solving the problems of Euclid; the other was the study of philosophy under Mark Hopkins.

In 1870 he received the degree of Bachelor of Arts and was elected to the honor society, Phi Beta Kappa. It is probable that at this time he had decided to follow a career of teaching and investigation, but it seems likely that he doubted whether he could find an opportunity to teach natural history, for in after years he said that he was in doubt when he left Williams whether he should teach mathematics, Greek, or biology. However proficient he may have been in the two former, there can be no doubt that by nature, early training, and inclination he was especially fitted for the career which he later entered. As indicating the manner in which he was "finding himself" at this time, the following extract from a letter of his cousin, the Rev. William J. Cleveland, is of interest:

> On another occasion, I think it was in 1869 or '70, after I had graduated, he visited me at Orange, N. J, and was full of the idea of teaching. He had with him a big lot of specimens of one kind and another, and his ambition was to try the experiment of giving public lectures. Enlisting me as assistant in a business way in this enterprise, a hall was engaged and announcements made in a small town "up the road" from Orange. I do not recall whether it was Milburn or Chatham, but at one of them he delivered what, no doubt, was his first public lecture. There was not a big crowd, but my recollection is that there was a very respectable and interested audience, and that all passed off nicely. He was in no sense oratorical or florid, but he went straight to his subject and on with it to the end, relying solely upon the interest of the subject itself, which was so great to him, to hold the attention of the audience.

I have tried hard, but with very meager results, to recall the topic and subject-matter of the lecture. I feel quite sure now, however, that the subject was "Mollusks," but I remember nothing of what he said except that he spent considerable time, as it seemed to me at the time, in explaining to the audience what Mollusca were

I believe his only object then was to try the experiment of giving a public lecture and to find out how he stood the ordeal. For that reason, perhaps, he chose a (then) small and out of the way place, and the whole venture was managed in the most quiet and unpretentious way. As I remember, no hand-bills or other printing of advertisements was resorted to to draw a crowd To give a lecture before a mixed audience in some public place and get enough out of it financially to fairly meet expenses, was all he aimed at That experience, no doubt, had some influence in convincing him that the class room rather than the platform was the place where he could do his most efficient work.

Following his graduation from college, young Brooks spent the year 1870-71 in business with his father, who was an importer and wholesale dealer in crockery, china, and glassware. Prof. E. A. Andrews, in his biographical sketch (Johns Hopkins University Circular, No. 212, January, 1909), says that during this year "he exhibited characteristic interest in the solution of problems and distaste for such mechanical drudgery as had only practical and not theoretical ends in view, by the invention of a calculating machine to lessen the amount of unprofitable manual labor." There is evidence that he continued his reading and study during this year, as much as his other duties would permit, and he and other young men continued to meet at his club for talks and discussions.

In the fall of 1871 he entered definitely upon his career as a teacher. He was employed as one of the masters at De Veaux College, Niagara Falls, New York, where he remained for two years. His ability to win the confidence, respect, and affection of his students was notable even at this early stage in his career. He had a way of not only interesting his scholars, but also of attaching them to him personally. The Hon. Herbert P. Bissell, of Buffalo, New York, who was a student at De Veaux College at that time, has written the following concerning Professor Brooks:

I have consulted with several old De Veaux boys, but none of them could add very much to my own knowledge of Professor Brooks. We all remember him as a man devoted to scientific research and constantly

studying the geology and the flora and fauna along the Niagara River I recall the interest he would take in any geological specimens that we would find underneath the high bank of the Niagara River. He would give us his opinion promptly as to the geological age to which the specimen belonged, etc His work at De Veaux College was most satisfactory; he was an excellent and interesting teacher and, as I have intimated, devotedly attached to scientific investigation

He remained at De Veaux College for two years, and then entered upon the professional course of training in zoology for which he had been planning and preparing. At Harvard, Louis Agassiz was at the climax of his wonderful career, and many young men, who afterward became leaders in biology, went there to study under this great master. In particular in the summer of 1873 the establishment of Agassiz's new seaside laboratory on the island of Penikese, in Buzzards Bay, attracted wide attention. This new departure, the first of the summer schools, was projected by Agassiz in the preceding winter; the island and a fund for the establishment of the school were given by Mr. John Anderson, of New York, in March, and the large buildings were hastily constructed, and were scarcely ready for occupancy when the school opened early in July. Between fifty and sixty teachers and investigators were present, and among these was Brooks. From that time until his death he remained a student of marine life. The sea, with its teeming multitudes of living things, always had a particular charm for him, not merely because of the interest and variety of its forms of life, but also because it was probably the scene of the earliest acts in the drama of evolution.

From this time forward throughout almost his whole life he spent a part, at least, of every summer at the shore. In 1874 he was again at Penikese at the last session of that famous but short-lived laboratory. In 1875 he was with Alexander Agassiz at his private laboratory in Newport, Rhode Island, working on the embryology of Salpa, and tutoring one of Mr. Agassiz's sons. In 1878 began the sessions of the Chesapeake Zoological Laboratory, which he founded and directed for many years. In the summers of 1888 and 1889 he was at the U. S. Fish Commission Laboratory at Woods Hole, Massachusetts, and in later years he was frequently at the Commis-

sion's Laboratory at Beaufort, North Carolina. He was a trustee of the Marine Biological Laboratory almost from its foundation until his death. In the summers of 1905 and 1906 he was at the marine laboratory of the Carnegie Institution of Washington, at Tortugas, Florida. His scientific life was thus closely identified with marine laboratories, beginning with the earliest of these at Penikese, and ending with the latest at Tortugas.

In the fall of 1873 he entered the graduate school of Harvard University, where he continued two years, receiving the degree of Doctor of Philosophy in 1875 At Cambridge he came to know several zoologists whose work and influence helped in some measure to shape his career. First among these must be named Louis Agassiz, of whom Brooks occasionally spoke in later life and whose influence upon him was profound though brief. Agassiz died in December, 1873, and Brooks' association with him was thus limited to the summer session at Penikese and the autumn term at Harvard. Among others whose influence he felt must be mentioned Alexander Agassiz, McCrady, and Hyatt.

While at Harvard Brooks and some other young zoologists lived in an old wooden building known as Zoological Hall, which stood where the Peabody Museum now stands. Professor Birge, who lived in the same building and thus saw Brooks frequently, remembers that he lived very simply and was apparently supporting himself, and that his usual carelessness of dress was emphasized by the fact that he mended his torn clothes with white string. His life was studious and generally solitary, save for the companionship of a great St. Bernard dog, "Tige," who always walked with him when he went out and who occupied most of his bed at night. "I hardly think," says Professor Birge, "that any of his ideals were shaped by the men with whom he worked. He read much and thought for himelf. One day he brought me a new copy of Darwin's Origin of Species, and when I asked him what this meant, he told me that he had borrowed mine one day when I was out, and, having kept it a good while, had written so many notes in it that he preferred to buy me a new copy rather than give the old one back."

In the summer of 1875, after his graduation from Harvard and before his visit to Mr. Agassiz's laboratory at Newport, in August and September of that year, he was instrumental in organizing a laboratory for instruction in Biology in Cleveland. As no fees were charged for this course it seems probable that his purpose was to gain experience in teaching, as well as the purely disinterested aim of establishing an inland Penikese for the instruction of teachers and students of natural history. In his address at the dedication of the new biological laboratory of Western Reserve University, in 1899, he described that enterprise in the following words:

It was my good fortune to have a share in one of the first attempts to organize laboratory instruction in Cleveland, and I hope you will pardon me if, on this occasion, my mind runs back to this old undertaking In 1875 three young men who had begun to train themselves as naturalists, came together for their summer vacation, at their homes in Cleveland They were Theodore B. Comstock, afterwards President of the University of Arizona; Albert H. Tuttle, now Professor of Biology in the University of Virginia, and myself We were filled with enthusiasm for our work, and, like all earnest students from Chaucer's day to this, as glad to teach as to learn, and we determined to organize a summer class for laboratory instruction in zoology and botany Money for our expenses was liberally supplied by R K. Winslow, Leonard Case, and other citizens; the authorities granted us the use of the old high-school building on Euclid avenue near Erie street, and we were soon able to issue notices of our undertaking, and invitations to all who wished to join the class, asking them to do so without the payment of any fee Some twenty-five were soon enrolled, most of them teachers, some from a distance, and work was begun with a class which shared all the earnestness and enthusiasm of their instructors We had daily lectures or demonstrations, followed by four or five hours of work in the laboratory, while two afternoons in each week were given to excursions to Rocky River, Cuyahoga Falls, and other places favorable for the out-of-door study of nature As a small steamboat had been placed at our service, we made two excursions upon the lake, and thus gave to the class an opportunity to learn the use of the naturalist's dredge for collecting the animals of the bottom. Our work was in part the study of the animals and plants which we obtained on these expeditions, and we also made use of a supply of marine animals which had been gathered for the purpose at the seashore.

This account is interesting not merely as a bit of local history, but rather because it reveals thus early in his career his

love of teaching and his methods of instruction; the latter, we may be sure, largely influenced by his experience at Penikese.

During the year 1875-76 Brooks was assistant in the museum of the Boston Society of Natural History This was practically his only experience in museum work He was not a museum man, being one of the first zoologists in this country to demonstrate in practice that the museum is distinctly inferior to the laboratory as a means of teaching and research Apart from a small teaching collection he undertook to establish no museum at the Johns Hopkins University, and such collections as he had were for use rather than for exhibition If a student needed for the sake of his research to dissect a museum specimen, he might feel certain that Doctor Brooks would offer no objection. He appeared to be wholly lacking in that reverence for specimens as such, which the typical museum man is supposed to have Some of his early students who had been trained in the museum methods then prevalent at some of our oldest and largest universities have confessed that 'when they went dredging with Brooks it made their hair stand on end to see the way in which he chucked material overboard.' With him research was the all-important thing, to which collecting and collections were always subordinate. The writer remembers that on one occasion he brought a distinguished medical man into the students' laboratory in Baltimore, and after showing him a series of sections of a larval Amblystoma, said to him: "Here is a little piece of glass which you can carry in your vest pocket, and which is worth more to one who wishes a knowledge of anatomy than a whole museum full of specimens."

On the founding of the Johns Hopkins University in 1876 Brooks applied for and obtained one of their twenty famous fellowships, which have done so much to change the character of university work and ideals in this country. Before he entered upon his fellowship his abilities as a teacher were recognized and he was appointed associate in biology. In 1883 he was appointed associate professor of morphology, and in 1889 professor in that subject. On the retirement of Prof. H. Newell Martin from the headship of the biological department in 1894, Professor Brooks became head of the department and

continued in that position until his death His active scientific life was therefore coextensive with that of the Johns Hopkins University, and his love of the biological department, and his loyalty to his university were always evident.

CHARACTERISTICS AS TEACHER AND INVESTIGATOR.

Although his publications were numerous and important, I think that his influence was greatest and most far-reaching in his work as a teacher and scientific director To few zoologists, perhaps to no other in the history of this country, has it been given to direct the work and shape the scientific ideals of so large and influential a body of young men. Among those who took their doctor's degrees under him are more than a score of the leading zoologists of this country, while many other distinguished scholars of this and foreign lands were his pupils.

As a teacher, Professor Brooks was characterized by his breadth of view and his interesting and illuminating style, rather than by his accuracy in details. Like all great teachers, he knew that the primary purpose of teaching is inspiration and illumination, and that information is only of secondary importance. A candidate for the doctor's degree expressed to Professor Brooks, on the morning after his major examination, his mortification that he had blundered in answering one of the questions. With apparent seriousness Brooks said: "Your mistake is a serious one, for it makes you responsible for misinforming my whole class on that subject; I used your answer in my lecture this morning."

His lectures were often vivid and picturesque, as well as clear and logical; and this, joined with his habit of taking little for granted on the part of his hearers and of dealing with the broader and more general phases of a subject, made his lectures interesting not only to biologists, but also to those having no special knowledge of the subject. He invariably lectured without notes, and yet his lectures were so orderly and logical that they bespoke the logical character of his mind. Professor Howell in his memorial address (Johns Hopkins University Circular, No. 212, January, 1909) said, with regard to this, that "when it was known that Brooks was to give a paper

before the scientific association of the university it was a custom for men in all the graduate departments to attend the meeting, so much did they appreciate the charm and clearness with which he could present the problems of his subject." I well remember the first time I saw and heard him; it was on the occasion of the annual opening of the graduate school in the fall of 1888. His appearance was neither impressive nor prepossessing, but when he began to speak the closest attention was paid to him. In fascinating terms he described the beauties of the Bahama Islands, with their cocoanut palms and coral reefs; and I shall never forget the enthusiasm and the calm but almost dramatic manner with which he described the finding of the eggs of Gonodactylus in the twilight of his first day in the Bahamas. Equally vivid are the memories in the minds of all his students of his description of the way in which a starfish eats an oyster; of the comparison of a starfish with a sea urchin; of the structure and movements of a jelly fish; of the structure of a squid (in which his own body represented the visceral mass and his coat the mantle); of Salpa, "a barrel with muscular hoops," or Pyrosoma, which at night looked like "a redhot cannon ball." Most delightful, too, were his references to the history of zoological discovery, as, for example, Aristotle's knowledge of the relationships between the various members of a colony of bees, or Chamisso's discovery of the supposed alternation of generations in Salpa.

His blackboard drawings added very much to the interest and value of his lectures; with a firm, even hand he would sketch the form he was describing, and he rarely needed any other eraser than his forefinger. He had learned, early in life, to draw on the blackboard with both hands, by observing the work of Prof. E. S. Morse, while lecturing in Cleveland. He was really an artist of considerable ability and his published drawings were made with much care; in general, they were not only accurate, but also artistic He was a great believer in pen and ink drawings, and the time and care which he devoted to putting in round and equidistant stipples seemed excessive, until one learned that these were times of reflection with him. His fondness for innovation was shown by his adoption, at one time, of a method of drawing with lithographic

pencils on paper, which drawings were then transferred directly from the paper to the stone. In later years he made much use of sepia washes, and he had all his students using them He expected all his students to learn to draw; to some of them he would say time and time again, "You'd better learn to draw," apparently unmindful of the fact that he had given this advice before, and that they were trying to learn as rapidly as possible; and sometimes, when shown a drawing of which the maker was rather proud, his only comment would be, "You can't do anything well without patience"

He loved to work with simple apparatus, and his technique was never complicated. He never mistook paraphernalia for science, and he went directly to the end he sought. He had a great fondness for primitive methods, and used to advise his students to learn to cut free-hand sections, and to use some of the oldest methods of staining and imbedding. At one time he had some of his students repeating ancient history in trying to imbed tissues in soap, and to more than one who asked him for advice about staining microscopical preparations he recommended Beale's Carmine; the results were always unsatisfactory, but in the meantime the student had learned something about the historical development of staining methods, and, best of all, had also learned to rely upon himself rather than upon Doctor Brooks One such student, after laboring for some weeks with Beale's Carmine, saw Doctor Brooks and told him that he could not get satisfactory results After waiting in vain for some response, he ventured to ask whether Doctor Brooks had ever used the method Yes, he had "What did you think of it?" "'Twasn't worth a damn." Not infrequently, when students asked him to suggest some topic for research work, he would recommend some wholly impractical thing, such as the study of siphonophores at Woods Hole or the study of Amphioxus at Beaufort; and such students were left to find their own problem and to work out their own salvation.

Although he would present a subject in his lectures in the clearest and most entertaining manner, he rarely, if ever, attempted to smooth the path of the investigator; the latter was to a very large extent thrown upon his own resources. He

believed so thoroughly in the law of natural selection, as he once said, that he thought it was best for a student to find out for himself, as soon as possible, whether he was fitted for independent investigation or not, and by this rigid discipline the unfit were weeded out from the fit. This was certainly no school for weaklings, but it afforded magnificent training for those who had ability and determination. For those who endured this ordeal he maintained the warmest regard, and his interest and pride in the work of his students was as marked as it was stimulating.

Throughout the greater part of his life he did most of his research work at night; even the preparation and study of microscopical objects were frequently done by lamplight. He was quite proud of a little device of his by means of which he could imbed objects in paraffin by the heat of his student lamp, which served to illuminate his microscope. It was his custom, after his day's work at the university, to spend the evening with his family, frequently in reading aloud or in playing cards, and then, after all others had retired, he began his work. With his feet wrapped up in blankets to keep them warm he would write, or use his microscope, far into the night. In his work at the shore he would work all day, or all night, as the need might require or his inclination prompt. In his last years night work was no longer possible for him, and he turned to music for recreation, having discovered almost by accident that he had a great fondness for music, and that this liking could be gratified by means of an automatic piano. The last time I saw him we sat up until after midnight playing compositions by great musicians.

In spite of the fact that he was, during the course of his life, interested in many things, he was rarely interested in more than one thing at a time; and this sometimes led to an apparent lack of sympathy with the work of some of his students which was more apparent than real. Occasionally, when he was appealed to for some explanation of some published statement of his, he would say, "I have forgotten all about that now." Often when asked a question, he would say, "I don't know," when he knew better than anyone, although, at the time, the subject was out of his mind. To one of his students

who was at work upon a cytological problem, he mildly protested that such work was not morphology; and to one who offered him a thesis on cell-lineage, he remarked, "This university has accepted theses on counting words; I suppose it might accept one on counting cells."

But though he sometimes disagreed with the conclusions of his students, he never attempted to dictate to them. They were treated as absolutely free and independent investigators, and he usually assumed no responsibility for their work or results.

He lived with his students on terms of comradeship. Indeed, between himself and them there existed a real but undemonstrative affection, which was shown on his part, not merely by solicitude for their safety when they were in danger, but by many little kindnesses at the laboratory and in his home. In particular he used to refer with pride and sorrow to those of his students who had died: Rice, Bruce, Humphrey, and Conant. On one of my visits to Baltimore he led me without a word to the tablet which had been placed on the wall of the laboratory in memory of Humphrey and Conant, both of whom lost their lives of yellow fever on their expedition to Jamaica in 1897 We both stood and silently read the tablet, and then as we turned away he said, simply but with emotion, "I thought you would like it." When once relations of comradeship had been established with his students, neither time nor separation changed these relations, and they never needed to be renewed. When attending the International Zoological Congress in Boston, he saw in the hotel lobby a former student whom he had not seen for nine years. He spent no time in renewing acquaintance, but went up to him, as if there had been no break in their associations, and said, "Do you know where I can get a shoestring?" There was a sort of helplessness or lack of worldly wisdom on his part which made his students feel responsible for him, and which increased their affection for him. His interest in his former students was genuine and hearty, though he rarely expressed it to the person concerned. He did not lose his critical judgment in his affection for his students, though he often showed that he was proud of their accomplishments. "One of the joys of

a teacher," he once said, "is to see his students surpass him." On the other hand, his students delighted to honor him; and on the occasion of his promotion to a full professorship, on his fiftieth birthday, at the twenty-fifth anniversary of the founding of the Johns Hopkins University, and at the International Zoological Congress in Boston, they showed him how deep a place he held in their affections. On December 31, 1908, sixty of his former students met at a dinner in Baltimore to pay honor to his memory, and the occasion was one of delightful reminiscence and of grateful recognition of indebtedness to him.

THE CHESAPEAKE ZOOLOGICAL LABORATORY

In connection with his work as teacher and director must be mentioned the establishment by him of the Chesapeake Zoological Laboratory in 1878. The great influence which his experience at Penikese had upon him has already been mentioned. To a large extent the direction and character of his research work was determined by this experience, and its influence was apparent in all his teaching as well as in his research. We have seen that it led him to organize a second "Penikese" at Cleveland in the summer of 1875, and one of his first acts at the Johns Hopkins University was the organization of the Chesapeake Zoological Laboratory. The stimulating influence which this laboratory had upon the research work of Doctor Brooks is shown by his bibliography, where it may be seen that after the first session of that laboratory his annual output of work was increased at least fourfold. And the importance of the laboratory in the development of the biological department of the Johns Hopkins University and in the general advance of zoology in America may be estimated from the large number of students who worked at the laboratory and the large number of papers which they published. Doctor Brooks expected all of his graduate students to spend a season or more at this laboratory. He rightly estimated this as the most valuable experience a student of zoology could have; for in this way the student became acquainted with animals under natural conditions; he had opportunities of becoming a broadly trained natu-

ralist, and he could find his own problems for work and become an independent investigator.

The Chesapeake Laboratory, unlike the one at Penikese, was not limited to one place; it consisted neither of buildings nor equipment, but of men and ideas. For the first few years of its existence it was located at several different points on Chesapeake Bay, afterwards it was located at Beaufort, North Carolina; then at different places in the Bahama Islands, and finally in Jamaica. In the various expeditions of Brooks and his students to these different places they made not only a thorough biological survey of each region, but they did work of most fundamental and far-reaching importance on the various groups of animals found. Out of these expeditions has grown the beautiful and permanent station of the U. S. Fisheries Bureau at Beaufort, North Carolina, in which Brooks took great interest and pride. It was on these expeditions that his students came to know him most intimately and affectionately In the memory of each of them is fixed some scene of his enthusiasm over the discovery of a rare specimen or of an unknown stage in some life history; his long vigils full of exciting discoveries; his quiet talks on nature and philosophy, after the day's work was done.

The Chesapeake Zoological Laboratory occupied so large a place in the life and work of Professor Brooks that it seems desirable to reproduce here, in his own words, a more detailed account of the aims and history of that laboratory during its first nine years. The following is taken from a report by Professor Brooks on "The Zoological Work of the Johns Hopkins University, 1878-86," published in the Johns Hopkins University Circulars, Vol. 6, No. 54:

In natural science the policy of the University is to promote the study of life, rather than to accumulate specimens and since natural laws are best studied in their simplest manifestations, much attention has been given to the investigation of the simpler forms of life, with confidence that this will ultimately contribute to a clearer insight into all vital phenomena.

The oldest forms of life are marine: every great group of animals is represented in the ocean, while many important and instructive groups have no terrestrial representatives, omitting the insects, more than four-fifths of the known species of animals are marine, and the total amount

of animal life in the ocean is incomparably greater than that upon the land In a word, the ocean is now, as it has been at all stages in the earth's history, the home of life, and it is there, and there only, that we find the living representatives of the oldest fossils, and are thus enabled to study the continuous history of life from its simplest to its most complex manifestations

On the sand flats at the mouth of the Chesapeake Bay, we find, living side by side, animals like Lingula, Amphioxus, Limulus and Balanoglossus, which are the representatives of some of the oldest and most primitive types of animal life, and all attempts to trace out the natural relationships of any group of animals, lead us at once to forms which are found only in the ocean

The animals which have contributed most extensively to the formation of the earth's crust, the corals and foraminifera and radiolarians, abound in the ocean today, and it is only by studying their life, by observations at the seashore, that we can understand and interpret their geological influence

Nearly every one of the great generalizations of morphology is based upon the study of marine animals, and most of the problems which are now awaiting a solution must be answered in the same way.

For these reasons our chief aim in zoology and animal morphology has been to provide means for research upon the marine animals of the Atlantic coast, and for nine years, successive parties, composed of instructors, fellows and students in this department, together with instructors and advanced students from other institutions have spent at the seashore all the months in which marine work is practicable Their time and energy have been devoted to research rather than to the preservation of collections, and the wisdom of this course can be estimated by examination of the accompanying list of publications; all of which are based, either in part or entirely, upon researches which we have carried on at the seashore

The wisdom of our policy is well illustrated by the fact that the leading naturalist of America, himself the head of one of the largest scientific collections in the world, says in his annual report for 1884,* that the expenses of an immense natural-history collection are so great that it would be far cheaper, with the present facilities and the cost of travel, to supply the student with the necessary funds for valuable researches, than to go on for years spending in salaries of curators and the care of collections, sums of money which, if spent in a different manner, in promoting original investigation in the field or in the laboratory and in providing means for the publication of such original researches, would do far more towards the promotion of natural history than our past methods of spending our resources.

This fact has become widely recognized during the last ten years, as is shown by the establishment of marine laboratories by several of the

* Report of the Museum of Comparative Zoology, Cambridge, Mass

European institutions of learning; and in the summers of 1883 and 1884 we had with us at our laboratory a young English naturalist (Wm. Bateson) who had been provided by the Royal Society of London with funds for his researches, the results of which have recently been published in England.

The Johns Hopkins University was among the first to recognize and act upon this new departure in zoology, and our little marine station is almost as old as the great Naples laboratory Briefly stated its history is as follows:

In 1878 a small appropriation was made to enable a party of biologists from the University to spend a few weeks at the seashore in the study of marine zoology Through the influence of Maj. Gen. Q A Gillmore, the Secretary of War permitted us to occupy the vacant building at Fort Wool. Prof Spencer F Baird also exerted his influence with the Secretary of War in our behalf, and aided us in many other ways; furnishing us with dredging apparatus and with three small row-boats. The scientific results of our season's work were printed in an illustrated volume, the cost of publishing which was borne by the following citizens of Baltimore: Samuel M Shoemaker, John W. Garrett, John W McCoy, Enoch Pratt, P. R. Uhler, T B. Ferguson, Dr. Geo Reuling, President Gilman, Professor Martin and others.

In 1879 the appropriation for the maintenance of the laboratory was renewed, and in order to present an opportunity for studying the oyster beds of Maryland, the laboratory was opened in three of the barges of the Maryland Fish Commission at Crisfield, Maryland, a point which proved to be very unfavorable. Maj. T. B. Ferguson, the State Fish Commissioner, not only provided the barges for our accommodation, but he also fitted the steam yacht *Lookout* with dredging apparatus, and rendered us valuable help in dredging and collecting. Through his influence a small steam launch was also detailed from the U S. Navy for our use.

The next year the Trustees of the University voted to continue the laboratory for three years more, 1880–1–2, and they provided a liberal annual appropriation of $1,000 for current expenses, which was renewed annually in 1883–4–5–6, and was expended in rent, wages, fuel, laboratory supplies, repairs, etc They also appropriated the sum of $4,500 for permanent outfit, and most of this was used in the purchase of two boats; a Herreshoff steam launch twenty-seven feet long and eight feet beam, and a center-board sloop forty-seven feet long and fourteen feet beam.

After an examination of all the available localities the town of Beaufort, N. C, about four hundred miles south of Baltimore, was selected as the site for the laboratory, and a vacant house, suitable for the accommodation of a small party, was found and rented as a laboratory and lodgings for the party, and it has been occupied during the seasons of 1880–1–2–4–5, and by two students in 1886 As the director was, in 1883, a member of the Maryland Oyster Commission, the outfit of the labora-

tory was that year moved from Beaufort into the Chesapeake Bay, and we occupied a building which we rented from the Normal School at Hampton, Va As Hampton proved to be a very unfavorable place for our work we returned to Beaufort the next year, and we have accordingly spent five seasons at Beaufort.

During the season of 1886 the zoological students of the University were stationed at three widely separated points of the seacoast. A party of seven under my direction visited the Bahama Islands, two were at Beaufort, and one occupied the University table at the station of the U. S. Fish Commission at Woods Hole.

The party which visited the Bahamas consisted of seven persons, and our expedition occupied two months, about half of this being consumed by the journey.

The season which is most suitable for our work ends in July, and we had hoped to reach the Islands in time for ten or twelve weeks of work there, but the difficulty which I experienced in my attempts to obtain a proper vessel delayed us in Baltimore, and as we met with many delays after we started, we were nearly three weeks in reaching our destination

We stopped at Beaufort to ship our laboratory outfit and furniture, but the vessel, a schooner of 49 tons, was so small that all the available space was needed for our accommodation, and we were forced to leave part of our outfit behind at Beaufort.

We reached our destination, Green Turtle Key, on June 2d, and remained there until July 1st The fauna proved to be so rich and varied and so easily accessible that we were able to do good work, notwithstanding the shortness of our stay and the very primitive character of our laboratory. This was a small dwelling house which we rented. It was not very well adapted for our purposes, and we occupied as lodgings the rooms which we used as work rooms

RECORD OF THE VARIOUS SESSIONS.

For the following brief records of the various sessions of the Chesapeake Zoological Laboratory I am indebted in large part to Prof. E. A. Andrews:

1878: 8 weeks, Ft. Wool, Virginia; 7 members Brooks studied embryology of Lingula.

1879. June 25—August 8, Crisfield, Maryland; 11 members. Brooks studied the oyster Three barges served as laboratory and quarters. Swarms of mosquitos led to the abandonment of this locality early in August, and the removal of the laboratory to Ft. Wool, until September 15.

1880: April 23—September 30, Beaufort, North Carolina; 6 members. Laboratory and quarters were in the Gibbs house. A steam launch was bought and the laboratory equipped by means of an appropriation from the University.

1881 May 2—end of August, Beaufort, North Carolina, 12 members An "Elementary Seaside School" had been announced, with lectures by Brooks and S F Clarke, fee for the course, $25

1882. May 1—end of September, Beaufort, North Carolina; 8 members.

1883 May 1—October 1, Hampton, Virginia As a member of the Maryland Oyster Commission Brooks was obliged to spend this summer on the Chesapeake The new machine shop of the Hampton Institute was rented as a laboratory, and a fast sloop was added to the equipment. Wm Bateson there joined the party to study the development of Balanoglossus.

1884 June 1—September 19, Beaufort, North Carolina, 10 members The illness of Brooks obliged him to return after a month, leaving the laboratory in charge of H W Conn Bateson, who was again with the party, was also seriously ill

1885: May 23—September 15, Beaufort, North Carolina, 11 members Brooks became a licensed pilot to take the steam launch in and out of Beaufort Inlet.

1886. June 2—July 1, Green Turtle Key, Abaco, Bahamas; 7 members The party left Baltimore, May 1, in a small Bay schooner, chartered by the day, with Brooks as pilot. With head winds, mishaps and a stop at Beaufort to take on laboratory furniture they did not reach their destination until June 2

1887: March 1—July 1, Nassau, Bahamas; 12 members

After this session, owing to financial losses on the part of the University, the Chesapeake Zoological Laboratory was temporarily suspended and its outfit dispersed.

1888 and 1889 Brooks, with some of his students, was at Woods Hole, Massachusetts, as naturalist in charge of the U S. Fish Commission Station

1891· May 26—September 1, Kingston, Jamaica, 15 members. The Chesapeake Zoological Laboratory was established at Port Henderson, on the harbor opposite Kingston

1892: A party of three, in charge of Professor Andrews, was located at Alice Town, North Bimini, Bahamas Brooks did not go.

1893. April 20—July 23, Port Henderson, Jamaica, 7 members. Brooks did not go and Dr. R. P. Bigelow was acting director.

1894· April 7—July 7, Beaufort, North Carolina, 9 members. Brooks was present.

1895· June 6—August 13, Beaufort, North Carolina, 4 members Doctor Siegerfoos was acting director; Brooks was not present.

1896: April 29—July 30, Port Henderson, Jamaica; 4 members. Dr. F. S. Conant was acting director; Brooks was there for a while

1897· June–September, Port Antonio, Jamaica; 12 members Prof. James Ellis Humphrey was acting director Humphrey died there of yellow fever, August 12; Dr. Franklin Story Conant contracted the fever there, and died on his return to Boston in September.

1898 Beaufort, North Carolina, 6 members Prof H V. Wilson was director In this and all subsequent years students went, with little or no aid from the University, to the U. S Fish Commission Station at Beaufort

1901–1906 Brooks was again at Beaufort in 1901 and 1903, and at the Marine Laboratory of the Carnegie Institution at Dry Tortugas, Florida, in 1905 and 1906.

In twenty years the Chesapeake Zoological Laboratory provided facilities for more than 160 workers, and approximately 200 papers were published as a result of these sessions In reviewing this enterprise one cannot fail to be impressed with the great results accomplished with small financial outlay. For the purposes which Brooks had in mind the advantages of a laboratory whose equipment could be moved from place to place are most evident, and the need of such laboratories is not yet past. May the Chesapeake Zoological Laboratory, or some other worthy successor, continue this work, so well begun by Brooks!

On these various expeditions Doctor Brooks was interested not merely in zoology, but also in botany and geology, and in the customs, characters, and histories of the people among whom he was living. He took keen interest while in the Bahamas in following the route of Columbus from island to island. He advocated the establishment of a Columbus Biological Station in memory of the great discoverer. He was particularly interested in the Indians found by Columbus on these islands, and he wrote a very interesting popular account of them, and prepared a monograph on their physical anthropology based on a study of a collection of their skulls. His love of the artistic was shown in his vivid pen picture of "Life on a Coral Island" and "Aspects of Nature in the West Indies" The following letter, written to his brother while on his last scientific expedition, describes in his vivid manner a trip which he made into the Everglades:

THE JEFFERSON,
KEY WEST, FLORIDA, March 21, 1906

DEAR CHARLES · I am in the "hottest place in the U. S." in an overcoat and my thickest underclothing. I am to get off to the Dry Tortugas tomorrow, on an excursion of army officers, after having been ten days on the journey. It has been a pleasant and profitable journey on the whole, but the delays have been very tiresome.

Among other side excursions I have been where very few white men have been—into the Everglades—which I found most interesting and very different from what our geographies lead us to expect The whole interior of southern Florida is a great lake of pure spring water, covered with wild rice and reeds, and with a hard bottom, with no mud It is surrounded by a rim of limestone about 30 feet above the level of the lower land, and it overflows in rivers wherever the rim is low We went up a river, very deep and rapid, for about twenty miles, to the rapids, and we got up the rapids by towing on the overhanging branches to the top, where the big river at once became lost in the great shallow lake We picked out a tree on a little island about five miles away, and pushed through the tall reeds until we reached it We climbed the tree, and as far as we could see there was nothing but reeds in all directions. After eating our lunch we pushed back through the reeds and struck our river again; but I could not help wondering what would happen to us if we missed the river. The trip down the rapids, about half a mile, was most exciting, and I was nearly torn out of the canoe by some low branches.

On our way back we visited an alligator farm, where they hatch, from stolen eggs, the little alligators that are sold in our northern cities They also deal in rattlesnakes and owls and hawks. In one pond they had the biggest American crocodile known He is 19 feet long, big enough to drown a horse, and he is fed on live hogs. It must be very exciting to rob the nests of alligators and crocodiles If you ever have the opportunity to visit southern Florida you should do so.

Miami is the prettiest tropical town I have ever seen and well worth a visit.

Yours affectionately, W. K. Brooks.

PRINCIPAL PUBLICATIONS.

As a scientific investigator Brooks showed sound judgment, philosophic insight, and breadth of view. His method of work, like his manner of life, was calm and slow. He was not a prolific writer, and of the one hundred and fifty titles, more or less, which appear in his bibliography, not less than thirty are preliminary notes or republications of other papers. Many of these papers are brief notes or abstracts, so that his total number of important contributions does not exceed one hundred. These were distributed over thirty-five years of his active life, so that he did not average more than three such papers a year. He did practically no research work on vertebrates, and his work on invertebrates was confined, almost exclusively to five groups, viz.: pelagic tunicates, mollusks, Molluscoida, higher

Crustacea, and Hydromedusæ. Altogether he published seventeen papers on tunicates, twenty-six on mollusks (fourteen of these on the oyster), three on Molluscoida, fifteen on decapod Crustacea, and sixteen on Hydromedusæ. In addition to these he published five or six general works and about sixty theoretical and popular articles, reviews, etc.

All of his papers, even those which deal with the most detailed and technical subjects, are generally understandable and as little technical as possible. As in his lectures, he took little for granted, began at the beginning, and kept his main topics prominent; moreover, he wrote in an entertaining manner, and his articles contain a certain popular quality while not lacking in scientific accuracy.

His first important paper was on the "Embryology of Salpa," and many of his later works, some of them monumental monographs, were devoted to the anatomy, embryology, and classification of this group of pelagic tunicates. Among these papers the most important are the following: "The development of Salpa," "Origin of the eggs of Salpa," "The anatomy and development of the salpa chain," "Monograph of the genus Salpa," and the "Pelagic Tunicata of the Gulf Stream." His latest work, left unfinished, and for which he had prepared hundreds of beautiful drawings, was a continuation of his great monograph on the genus Salpa. These works on the tunicates are too extensive and complicated to be summarized briefly, but some of his more important conclusions are the following:

1. In his earlier papers Brooks maintained that there is not a regular alternation of generations in the life cycle of salpa, between the solitary individuals and those united into chains, as had been generally held since Chamisso's work on salpa, but that the solitary salpæ are females, and that they produce by budding the chain individuals, which are males. Into each of the chain salpæ, before it is set free, an egg is placed, which comes to maturity in the chain form, and ultimately develops into another solitary individual, thus completing the life cycle. In his later works, as Professor Metcalf has pointed out in a letter to the writer, Doctor Brooks departed in several respects from this early conception. He showed very clearly that the solitary salpa is an immature sexual form, which passes its

germinal cells into the chain individuals, where they reach maturity. Since these germinal cells give rise to both ova and spermatozoa, both solitary and chain forms may be considered potentially bisexual, though the solitary forms never contain mature germ cells.

2. In the formation of the salpa chain a stolon, or stalk, which grows out from the solitary salpa is constricted at intervals, thus giving rise to the members of the chain. The stolon is bilaterally symmetrical, its planes of symmetry coinciding with those of the solitary salpa which bears it, and, at first, the planes of symmetry of every member of the chain coincide with those of the stolon and of the solitary salpa. Very soon, however, a twisting of the chain occurs which leads to the formation of a double row of salpæ, each row with the dorsal surfaces of its members turned outwards, while the ventral surfaces of the two rows are turned toward one another, and the right sides of one row and the left sides of the other are turned toward the base of the stolon.

3. The salpa embryo, which develops from the fertilized egg into the solitary salpa, "is blocked out in follicle cells which form an outline or model of the general features of the embryo. While this process is going on the development of the blastomeres is retarded, so that they are carried into their final positions in the embryo while still in a very rudimentary condition. Finally, when they have reached the places which they are to occupy, they undergo rapid multiplication and growth and build up the tissues of the body directly, while the scaffolding of follicle cells is torn down and used up as food for the true embryonic cells."

4. The salpa embryo is connected by a placenta with one of the members of the chain, and is nourished by placenta cells which migrate from the placenta into the embryo. The placenta is thus an organ which nourishes the embryo, not by the transfusion of blood, but by means of giant cells which in the placenta receive nourishment from the blood of the parent, and then migrate into the embryo, there to break down and supply food to the embryo.

But Brooks' work on salpa is not merely a description of the anatomy, embryology, and classification of these interesting

tunicates, for it deals in original and philosophical manner with such problems as the origin of chordates, the origin of pelagic animals, the discovery of the ocean bottom, and the effects of this upon the evolution of life.

Another major line of his work was on the anatomy and embryology of the Mollusca. One of his first papers was on "An organ of special sense in the lamellibranchiate genus Yoldia," this sense organ being a long retractile tentacle, half way between the siphon and the lower edge of the mantle on the right side. This paper was soon followed by one on "The embryology of the fresh-water mussels," in which the entire development of *Anodonta implicata* is described in brief outlines, and the conclusion is reached that the larva, or glochidium, is a specially modified stage, adapted to a special purpose, and having no bearing on the question of the origin of the group. Both of these papers are brief abstracts of three pages each, and they were read at the meetings of the American Association for the Advancement of Science in 1874 and 1875. In a paper "On the affinities of the Mollusca and Molluscoida" (1876) he concluded that Brachiopoda have been derived from Vermes, Polyzoa from Brachiopoda, and the Molluscan Veliger (the prototype of the Mollusca) from Polyzoa. The Lamellibranchiata he held to be a side branch, and not ancestral to the group of mollusks as a whole. Later (1879), in his paper on "The development of Lingula and the systematic position of the Brachiopoda," he held that the Rotifera, Polyzoa, and Veliger were three branches which early diverged from the vermian stem. The Brachiopoda he held to be the most highly specialized members of the polyzoan branch, the Mollusca the most highly specialized of the Veliger branch. For these three branches he proposed the name Trochifera.

In his "Observations upon the early stages in the development of the fresh-water pulmonates" (1879) he observed the rhythmical nature of the process of cleavage, the formation of the ectoderm from the clear cells at the animal pole of the egg, the formation of the endoderm from the macromeres at the vegetative pole, and the lack of a continuous mesodermal layer in the embryo. He devoted particular attention to the fate of

the blastopore and the origin of the digestive tract; but since his observations were made exclusively on living material, he fell into several errors, mistaking the shell gland for the mouth, which he maintained appeared opposite the original position of the blastopore, and concluding that the macromeres fuse together, and afterwards bud out cells which form the alimentary canal. In the main the same remarks apply to his "Preliminary observations on the development of the prosobranchiate gasteropods," which appeared in the same year (1879). In this paper, and in a subsequent one on the "Acquisition and loss of a food yolk in molluscan eggs," he devoted much attention to what is now known as the yolk lobe, or polar lobe, which he regarded as a "food yolk." This he believed to be in process of being lost in some cases, as, *e. g.*, the oyster, while it was being acquired in others. It is needless to say that this explanation of this problematical yolk lobe is no longer found to be satisfactory. In a brief paper on the "Development of the digestive tract in molluscs" (1879) he reiterates his mistaken view that in gasteropods and lamellibranchs the blastopore is converted into the shell gland, and that the mouth forms at the opposite side of the embryo. With the exception of a single paper, published in collaboration with one of his students in the last year of his life, this list comprises all of his publications on the gasteropods. The paper just mentioned is entitled "The origin of the lung in Ampullaria" (1908), and is based upon the study of material which he obtained on his trip into the Everglades in 1906 (see p. 53). In brief, the conclusion of this paper is that the lung of this prosobranch has no ancestral connection with the lungs of pulmonates. "The gills, the lung, and the osphradium of Ampullaria arise simultaneously, or nearly so, and they must be regarded as a series of homologous organs specialized among themselves in different directions."

During the second session of the Chesapeake Zoological Laboratory material was collected for a study of the later stages in the development of the squid, *Loligo pealii,* which resulted in the publication of two papers, one "The development of the squid," the other "The homology of the cephalopod siphon and arms." The most important conclusions of

these papers are. (1) That the embryonic record of the Cephalopoda "has been simplified to a degree which is without parallel in the animal kingdom, and it is hardly too much to say that the ontogenetic process furnishes us with no knowledge whatever of the phylogeny of the group;" (2) that the yolk sac of the cephalopod embryo is the homologue of the gasteropod foot; (3) "that if the epipodal folds of the gasteropod are regarded as homologous with the cephalopod siphon, the arms of the cephalopod must be regarded as independently acquired structures; whereas if we regard the arms as modifications of the epipodal folds, we must consider the four siphon folds as independently acquired structures;" and (4) "the common ancestor of the gasteropods and cephalopods must have been an unspecialized form, and we cannot expect any valuable results to follow from the attempt to compare any part of the body of a cephalopod with structures which, like the epipodal folds, are not common to the Gasteropoda, but somewhat exceptional."

All his other publications on the Mollusca, fourteen in number, deal with the development and propagation of the oyster. In 1878, during the first session of the Chesapeake Zoological Laboratory, he attempted to find young oysters in the gills of the female, as had been described in the case of the European oyster, but without success. In May, 1879, he went to Crisfield, Maryland, the center of the oyster industry on the Chesapeake, and settled down to study the problem of the development of the oyster. "On Monday, the 21st," he says, "I opened a dozen fresh oysters, and found three females, with their ovaries filled with ripe ova, and one male, with ripe spermatozoa. I mixed the contents of the reproductive organs of these four oysters, and within two hours after the commencement of my first experiment I learned by the microscope that the attempt at artificial fertilization was successful, and that nearly all of my eggs had started on their long path toward the adult form. . . . I have accumulated enough evidence to show, beyond the possibility of doubt, that so far as the oysters of the Chesapeake Bay, during the summer of 1879, are concerned, the eggs are fertilized outside the body of the parent, and that during the period which the European oyster passes

inside the mantle cavity of its parent, the young of our oyster swim at large in the open ocean."

This was the beginning of his many publications and his years of labor on the development and propagation of the oyster. His first paper on "The development of the American oyster" was very favorably received, and was republished in whole or in part in many American and foreign journals In recognition of the importance of this work, he was awarded a medal by the Société d'Acclimatation of Paris In 1882 the General Assembly of Maryland established a commission to consider ways and means to "Perpetuate the oyster beds of the Chesapeake," and Doctor Brooks was appointed chairman of this commission by the governor. The university released him from active duties, in order that he might devote his entire time for eighteen months to the study of the economic aspects of the oyster problem. A laboratory was established at Hampton, Virginia, where experiments were carried out on the propagation of oysters, and extensive surveys of oyster beds were made. The report of this work was published in 1884, in a quarto of 183 pages, 7 maps, and 13 plates. The legislature paid little attention to the recommendations of this report, and Doctor Brooks undertook by public lectures and newspaper articles to arouse public interest in the subject. To this end he published in 1891 a popular work on this subject, entitled "The Oyster," which was republished in a second edition in 1905 His absorption in this work was so complete that he talked oysters in season and out of season. The story is current that at a university reception a society woman attempted to engage him in small talk; he listened mutely for a while, and then was heard to say suddenly, and with animation, "Madam, the Maryland oyster is being exterminated."

Finally, in 1906, the legislature of Maryland passed a law for the protection and propagation of oysters along substantially the lines advocated by Doctor Brooks, and the satisfaction which he felt in this happy culmination of his long campaign was very great.

A third line of work to which he devoted much attention was the embryology and larval history of the higher Crus-

tacea,* and altogether about fifteen papers dealing with these subjects were published during a period of fifteen years, from 1879 to 1892, his first contribution on the larval stages of *Squilla empusa* representing some of the "Scientific Results of the Chesapeake Zoological Laboratory" for 1878. At Beaufort, in 1880, his interest in this subject deepened, for he saw in the structure and metamorphosis of these animals a means of attacking several larger problems, such as the laws of larval development, the analysis of secondary adaptations, and the meaning of metamerism in both lower and higher animals.

The works by which Professor Brooks will be best known to all future students of crustacean zoology are undoubtedly his large monograph on "Lucifer: a study in morphology," published in the Philosophical Transactions of the Royal Society of London for 1882, and his "Report on the Stomatopoda," which appeared as part of the sixteenth volume of the Scientific Results of the Challenger Expedition in 1886. Not only did he discover that the shrimp, Lucifer, emerged from the egg as a true Nauplius, but, what was even more novel, that the egg itself underwent a total and regular segmentation, and gave rise to a gastrula of the invaginate type. After tracing the metamorphosis through nine distinct stages, and making exhaustive comparisons, he concludes that the highly peculiar segmentation and gastrulation are secondary, but that the three-jointed Nauplius represents a true ancestral form, "and nothing but the supposed necessity of believing that the primitive Crustacea had a large number of somites and appendages opposes this view" He shows that the serial and bilateral homology, so evident in the Crustacea, cannot be explained by supposing that the ancestors of the Crustacea represented a community of independent parts. In his Report on the Stomatopoda he considers this subject again, and concludes that serial homology may be due "to heredity from the same part of the developing egg, rather than from a remote ancestor." The report on the Stomatopoda is distinguished by the great ingenuity and mastery shown in classifying all of the

*For assistance in preparing this abstract of Brooks' work on the Crustacea, the writer is indebted to Prof. F H Herrick.

known larvæ of this sub-order and in tracing them to their proper genera, for he had no living material to work with, excepting the two species—*Squilla empusa* and *Lysiosquilla excavatrix*—which he had studied from the southern coast of the United States.

During the period from 1880 to 1883, Professor Brooks undoubtedly contemplated the preparation of a work on the higher Crustacea, of greater scope than anything which he later produced, and this was only partially fulfilled in the publication, in collaboration with F. H. Herrick, of "The embryology and metamorphosis of the Macrura," in the Memoirs of the National Academy of Sciences for 1892. Moreover, it should not be overlooked that one of his most notable papers, in which he described how a Stomatopod—*Gonodactylus chiragra*—was reared, for the first time, from the egg, and in which he traced all its successive stages in the living state, appeared as Chapter III of the latter work.

Another group of animals to which Professor Brooks devoted a large amount of attention is that of the Hydromedusæ. In the study and drawing of these beautiful and delicate forms he combined the enthusiasm of the naturalist and that of the artist. From 1880 to 1886 he published seven papers on the Medusæ, chiefly of the Beaufort region, culminating in his monograph on "The life-history of the Hydro-medusæ: A discussion of the origin of the Medusæ and of the significance of metagenesis" (Memoirs Boston Society Nat. Hist., Vol. 3, 67 pp., 8 plates) This work contains an account of his observations on the life-history of a Narcomedusa, a Trachomedusa, an Anthomedusa, and a Leptomedusa, the four species selected for study being "among the most abundant and characteristic of our Southern coast, yet none of them have been well studied." This is one of the most beautiful, complete, and satisfactory papers which Doctor Brooks wrote; the observations are beautifully recorded, the evidences from his own work and that of others are completely marshalled, and his conclusions give the satisfaction which comes from a broad outlook, an intimate knowledge and a logical presentation of a great subject. In brief, his conclusion as to the origin of the Medusæ and the significance of metagenesis are these: (1) The remote ancestor

of the Hydromedusæ was a solitary swimming hydra, or actinula, with no medusa stage, but probably with power to multiply by budding; (2) this became more highly organized, better fitted for swimming life, until it was converted into a medusa, with swimming bell and sense organs, developing directly from the egg, but exhibiting during growth the stages through which the race had passed; (3) after this the larva derived some advantage in becoming attached, either as a parasite or semiparasite, and in this condition it budded off other larvæ, all of which became medusæ; (4) the sessile life of the larva was so advantageous that it was perpetuated by natural selection and the primary larva lost its tendency to become a medusa, and remained a sessile hydra, budding off larvæ which became medusæ; (5) the primary larva acquired power to produce other larvæ, which remained permanently in the hydra state; and (6) finally, the communities thus formed became polymorphic by division of labor, and the sessile habit became so advantageous that the free medusæ became degraded into medusa buds on the bodies of the sessile hydras, or on the blastostyles. Following this monograph, he published six shorter papers on Hydromedusæ, the last appearing only one year before his death. A monograph on American jelly fishes, which he had worked upon for many years, was never completed, though many of the drawings and descriptions were used in some of the other papers named.

He wrote but one text-book, his "Handbook of Invertebrate Zoology," 1882, but this was so excellent that it has been a model for many subsequent books on that subject, and it is probable that if it had been handled by a larger publishing house its success would have been much greater. He was also the author of many scientific articles of a popular sort, in which kind of writing he showed unusual ability. He was inclined to look upon various human problems, such as the education and political position of woman, from the standpoint of zoology, and his popular discussions of the possible improvement of the human race, of instinct and intelligence, of heredity and variation, etc., were both novel and suggestive.

His chief interest was always on the philosophical side of biology, and into this he put a large part of his life work.

Even the special researches, some of which have been named above, were permeated by philosophical inquiry, and most of his books and later contributions were devoted to the deeper philosophical meanings of vital phenomena.

As a boy he had read the works of Darwin, and had been immensely impressed by them, and to the last he yielded to no one in his admiration and reverence for that great master. Probably no other disciple of Darwin was more thoroughly acquainted with his works, and very frequently when criticisms of Darwinism appeared he would point out the fact that the critic did not understand what Darwinism is, or that Darwin had already met and answered the objection raised.

One of his earliest papers, entitled "A provisional hypothesis of pangenesis," which he read before the American Association for the Advancement of Science in 1876, contained the germ of many of his later theories and speculations. This germ is the hypothesis that, whereas fully established peculiarities are transmitted by asexual reproduction as well as by the ovum, new characteristics are transmitted only through gemmules, which are stored in the reproductive glands of the male, and are transmitted to the egg in fertilization. Gemmules from the body of the female may pass into the ova, but there is here no organ for the aggregation and transmission of them. "The male element is thus the originating, the female the perpetuating factor in the reproductive process. The female is conservative, the male progressive."

This speculation, which he sought to support by many observations, became the basis of a volume of 336 pages, entitled "The law of heredity," which he published in 1883. This volume, however, contained much of value besides the speculation named. In some respects it anticipated the Germ-plasm theory of Weismann and the Mutation theory of De Vries, and it won the highest commendation from Huxley and other leaders in biology. Like many other profound thinkers on the subject of heredity, he recognized that no hypothesis of epigenesis offers a satisfactory explanation of heredity, and that there is no escape from some form of the evolution hypothesis. The form which he adopts is Darwin's hypothesis of pangenesis, with the modification suggested above. He points out that it is not

necessary to assume that the germ is as complicated as the adult, since under certain conditions the descendants of a single cell may become modified in several divergent directions. He maintains that Darwin's hypothesis may be so simplified that the gemmules may be few in number, simple in their properties, and not infinitely small Nevertheless, this theory requires us to believe that the egg of one of the higher animals is complex beyond our powers of conception. It is interesting to note that he discusses (p. 131) those cases in which a hybrid resembles one parent or the other, but not both (what we now know as Mendelian inheritance), and he suggests a possible explanation by means of his hypothesis of pangenesis. In similar manner he discusses saltatory evolution (pp. 157, 296), and agrees with Huxley, Galton, and Mivart that nature does make considerable jumps (mutations), especially in the case of domesticated animals and cultivated plants. As instances of this kind he cites the sudden appearance of spike-horned bucks in the species *Cervus virginianus,* the ancon ram, the japanned peacock, and several similar cases among plants, and he "points out that our view of the cause of variation implies that any particular change should in itself be a fruitful source of still greater modifications, so that as soon as a tendency to vary becomes established it will continue to increase until an equilibrium is again established by the natural selection of those modifications which are adapted to the environment."

With regard to the determination of sex, he concludes that "sex is not determined by any constant law; that in certain animals and plants the sex is determined by certain conditions, while in other groups it is determined by quite different conditions" (p. 317). These are only a few of the subjects of present-day interest which are discussed in this book, and which he attempts to explain by his modified hypothesis of pangenesis, and although this hypothesis has no defenders at present, the book is still stimulating and suggestive.

It is interesting, and to many of his followers saddening, to see how far Brooks wandered in later life from the study of the physical phenomena of heredity and variation into metaphysical speculation. In two papers written in the last

years of his life, one of them entitled "Heredity and variation, logical and biological" (1906) and the other his address before the Seventh International Zoological Congress in 1907, entitled "Are heredity and variation facts?" he concludes that these terms "represent only imperfect mental concepts, and not facts, and that neither heredity, nor variation nor species can reside in germ cells, nor in chromatin, nor in gemmules The gradual disappearance of attempts to invent evolutionary hypotheses to account for individual development or ontogeny, and the return to a more epigenetic standpoint . . . seems to me a notable reformation. Ancestral development is as epigenetic as individual development. The being of an individual is not in itself, but in reciprocal interrelations between it and its environment. If these things are true, is it not time to have done once for all with the pre-Darwinian metaphysical notion of species as something which resides in germ cells and is handed down by a substance of heredity?"

This brings us to a consideration of his philosophical and metaphysical writings to which the last ten years of his life were devoted almost exclusively. The publications of this period include some eighteen or twenty papers on philosophical subjects, culminating in the book into which he put the best efforts of his life, and by which he hoped to be longest remembered, viz.: "The foundations of zoology" (1899). This book consists of a series of lectures which were originally delivered at Columbia University, and were published in the Biological Series of that institution. It deals with many subjects fundamental not only to zoology, but to science and philosophy in general. The keynote of this book is found in the following extracts from the introductory lecture: "I shall try to show that life is response to the order of nature—in fact, this thesis is the text of most of the lectures; but if it be admitted, it follows that biology is the study of response, and the study of that order of nature to which response is made is as well within its province as the study of the living organism which responds." Among such responses to the order of nature are various forms of adaptation, correlation, instinct, intelligence, volition, and responsibility, and the question arises as to whether such responses are mechanical. "I am myself unable

to discover, in the present status of biology, any demonstration of error in the assertion that life is different from matter and motion," but "I cannot find any contradiction between anything we find in our nature and the ultimate reduction of all nature, including all the phenomena of life and of mind, to mechanical principles; for most students of the principles of science agree that natural knowledge is no more than the discovery of the order of nature. . . . Order is no explanation, but a thing to be explained" "It is a hard thing," says Berkeley, "to suppose that right deductions from true principles should ever end in consequences which cannot be maintained." To which Brooks responds: "In my opinion there is nothing in the prevalence of mechanical conceptions of life and mind, or in the unlimited extension of these conceptions, to show that this hard thing to suppose is true."

It is as impossible to summarize this book as it would be to summarize the Book of Proverbs, or the Meditations of Marcus Aurelius. It is, indeed, a compilation of many meditations which appear to have been written down at many different times, and afterwards joined together with more or less care. The result is a book which contains more pithy, quotable sentences than can be found in any other book dealing with biology with which I am acquainted, but at the same time it is a book which is difficult to analyze, and in places difficult to understand. The titles of the chapters will, in a general way, give the trend of the book; these are: "Huxley and the problem of the naturalist," "Nature and nurture," "Lamarck," "Migration in its bearing on Lamarckism," "Zoology and the philosophy of evolution," "A note on the views of Galton and Weismann on inheritance," "Galton and the statistical study of inheritance," "Darwin and the Origin of Species," "Natural selection and the antiquity of life," "Natural selection and natural theology," "Paley and the argument from contrivance," "The mechanism of nature," "Louis Agassiz and George Berkeley." In the course of these lectures very many important facts and observations on the topics suggested are introduced, and the book is of value from this more usual standpoint of science, but attention is chiefly directed to the underlying philosophical significance of these phenomena. On the whole his chief

points of view may be summarized in his oft-quoted remark of Aristotle, that the "essence of a living thing is not what it is made of nor what it does, but why it does it," or, as he expresses it elsewhere, "the essence of a living thing is not protoplasm, but purpose;" and in the further statements which he draws from Berkeley, that "nature is a language," that "phenomena are appearances," and that "natural laws are not arbitrary nor necessary, but natural, *i. e.*, neither less nor more than one who has the data has every reason to expect." His system of philosophy was profoundly influenced by the writings of George Berkeley; his language resembles in its force and beauty the essays of Huxley, but his application of these to the foundations of science is his own.

On his fiftieth birthday, March 25, 1898, his former students united in presenting to him an oil portrait of himself (see page 71), together with a congratulatory address, and at the end of his book on the "Foundations of Zoology" he added on this date the following note:

> For you who have, at this time, for my encouragement, called yourselves my students, I have written this book which has been my own so long that I should part with it with regret, did I not hope that, as you study the great works to which I have directed you, you may still call me teacher If you are indeed my students, you are not afraid of hard work, so in this day of light literature, when even learning must be made easy, you must be my readers, and you must do double duty; for I take the liberty of a teacher with his pupils, and ask that, after you have read the book, you will some day read it again; since I hope that what may seem obscure, may, on review, be found consistent and intelligible.

Much that he has written still seems to me obscure, although I have read it more than once, but I bear in mind his parting request, and in the meantime profit by that which I do understand, and am charmed by the classical and almost poetical diction in which it is written. Whatever one may be inclined to say of his conclusions and theories, it cannot be denied that in an age when biological investigators have been content with discovering phenomena, he attempted to go back of phenomena to their real meaning and significance and to point out the relationship of these newly-discovered phenomena to the great cur-

rent of philosophy which has flowed down to us from the remote past.

In his review of this book, under the caption "A sage in science," David Starr Jordan said:

Brooks' lectures on the Foundations of Biology constitute a book that will live as a permanent addition to the common sense of science It belongs to literature as well as to science It belongs to philosophy as much as to either, for it is full of that fundamental wisdom about realities which alone is worthy of the name of philosophy Writers of literature have been divided into those with quotable sentences, such as Emerson and Thoreau, and those whose style runs along without break in the elucidation of matter in hand, as Hawthorne and Irving. To the former class Brooks certainly belongs His lectures are full of nuggets of wisdom, products of deep thought as well as of careful observation There is not an idea fundamental to biology that is not touched and made luminous by some of these sagacious paragraphs Whether it be to show the significance of some unappreciated fact, or to illustrate the true meaning of some complex argument, or to brush away the fine-spun rubbish of theory, the hand of the master is seen in every line . The stones which Doctor Brooks has chosen as "Foundations of Zoology" will remain for centuries, most of them as long as human wisdom shall endure The volume is a permanent contribution to human knowledge, the worthy crown of a life of wise thought as well as of hard work and patient investigation The biologists of America have long since recognized Doctor Brooks as a master, and this volume, the modern and scientific sequel to Agassiz's "Essay on Classification," places him in the line of succession from the great interpreter of nature, whose pupil and friend he was

HONORS, DEGREES, OFFICIAL POSITIONS

His abilities received early and generous recognition. Apart from his university advancement he received many honors. The honorary degree of LL. D. was conferred upon him by Williams College in 1893, by Hobart College in 1899, and by the University of Pennsylvania at the Franklin Bicentenary in 1906. In 1884, at the age of thirty-six, he was made a member of the National Academy of Sciences. He was chosen a member of the American Philosophical Society in 1886, and a Councillor of the Society in 1906; an Associate Fellow of the American Academy of Arts and Sciences in 1892; resident member of the Boston Society of Natural History in 1875, and corresponding member in 1877; corresponding member of

the Academy of Natural Sciences of Philadelphia in 1887; honorary member of the New York Academy of Sciences in 1898. He was also a member of the American Society of Zoologists, the New York Geographical Society, the Society of American Wars. He was a fellow of the American Association for the Advancement of Science, and of the Royal Microscopical Society.

As a result of his investigations on the development of the oyster, he was appointed by the governor of Maryland to be chairman of the Oyster Commission of that State; and he was also made Member Protector, Classe Peche et Pissiculture d'Exposition universelle d'Anvers, he also received the medal of the Société d'Acclimatation of Paris for his oyster work. A Challenger medal was given him for his work on the Challenger Reports; and he received a medal at the St. Louis Exposition of 1904, where he gave one of the principal addresses. He was Lowell Lecturer in Boston in 1901; one of the speakers at the American Museum of Natural History on the occasion of the unveiling of busts of American men of science during Convocation Week, 1906; and he gave one of the principal addresses at the Seventh International Zoological Congress in Boston, in 1907.

For nearly twenty years he was a trustee of the Marine Biological Laboratory at Woods Hole, Massachusetts; and in 1888 he was Scientific Director of the U. S. Fish Commission Station at Woods Hole. He was editor of the Results of the Chesapeake Zoological Laboratory; co-editor, with Professor Martin, of the Studies from the Biological Laboratory of the Johns Hopkins University; editor of the Memoirs from the Biological Laboratory, and a member of the board of editors of the Journal of Experimental Zoology.

All of these honors he prized highly, though modestly, and he rarely mentioned them except in facetious vein. It was characteristic of him, however, that he not infrequently mentioned with pride the fact that he held a U. S. Inspector's Certificate, licensing him as a pilot.

PERSONALITY.

Professor Brooks was a man of strongly marked individuality. In personal appearance he was short and stout, with straight dark brown hair and heavy dark brown moustache and eyebrows. While in Cambridge, and during the earlier years of his residence in Baltimore, he wore a full bushy beard. He sometimes allowed his hair to grow long, apparently because he disliked to take the time to have it cut. He used to say jocosely that he envied the man who did not need to have his hair cut, and who never wore a collar or necktie. He was generally careless, or rather thoughtless, of dress, and mere conventionalities counted for little with him. His best known portrait is the one painted by Thomas C. Corner, and presented to him by some fifty of his former pupils on his fiftieth birthday, March 25, 1898, a photographic copy of which appears on the opposite page. This portrait was afterwards loaned to the Johns Hopkins University, and it now hangs among the portraits of other distinguished professors of the university in McCoy Hall. It represents him in characteristic attitude, sedentary, meditative, careless of dress, and with that peculiar uplift of the eyes which with him usually preceded speech

He was slow and deliberate in his movements and speech, and undemonstrative in manner. In general he talked little, and in a low tone. When he had occasion to speak more loudly his voice assumed a rather high and piping quality. With him talking meant expressing ideas, not merely passing the time, and if he had no answer ready when a question was asked him he usually gave no answer until he was ready—it might be several days later—when he would answer as naturally as if the question had been asked only a moment before. These characteristics made him appear somewhat unique and picturesque, and gave rise to many charming anecdotes about him which his students and friends relate with merriment, but real affection.

In spite of his quiet reserve he was usually a very companionable man, and his company was sought and prized by his friends. On his part he was fond of his friends and neighbors, though he was often silent and absorbed in thought. At

such times he would occasionally interrupt his quiet reflections by some thoughtful and unexpected remark, such as, "The term supernatural is due to a misconception of nature; nature is everything that is."

His humor was quiet but genuine; he enjoyed a good joke, and would sometimes relate humorous stories, but never any of questionable propriety. His laugh was never loud, and his amusement was shown by a quiet chuckle and twinkling eyes. In particular he enjoyed telling of odd and interesting persons whom he had known, and of the amusing behavior of animal pets. For a puppy that destroyed a copy of Shakespeare he professed a high regard, but one that chewed up cheap novels was a worthless rascal.

His love of animals was deep seated, and between him and his pets there was genuine companionship. In particular his great dog "Tige" was his constant companion for many years. This "noble dog," as Prof. William James has called him, was seven-eighths St. Bernard and one-eighth mastiff, and weighed nearly 100 pounds. He lived with his master during his life at Cambridge, and later accompanied him to Baltimore, and many who knew Doctor Brooks in those days remember how nearly inseparable he and his dog were. On one occasion, when Professor Brooks was living in the country near Baltimore, he took an early train to the city, and put "Tige" in the baggage car. Before the train started "Tige" jumped out, and then, missing his master, he raced after the train and kept within sight for two and one-half miles, when he was lost to view; but he appeared at the laboratory several hours later, and quietly laid down at his master's feet. The affection which Brooks had for this dog was very great, and after "Tige's" death he was often mentioned as if he had been a dear human companion.

For another favorite dog which had been lost in transit between Baltimore and North Carolina, Brooks employed a man to make careful search over the entire line of travel, not because the dog was of commercial value, but because of his affection for him. His attitude toward all animals and plants is beautifully expressed in his introductory lecture on the "Foundations of Zoology," p. 17: "As for myself, I try to treat

all living things, plants as well as animals, as if they may have some small part of a sensitive life like my own, although I know nothing about the presence or absence of sense in most living things, and am no more prepared to make a negative than a positive statement."

Professor Brooks was interested in the welfare and practical needs of his fellow-men. In 1879 he gave part of an elementary course in biology for the teachers of the Baltimore schools. In 1882 he lectured before the employees of the Baltimore and Ohio Railroad on "Methods of locomotion in animals." He was also instrumental in establishing a public aquarium in Druid Hill Park. But his principal work of a practical character was on oyster and fish culture. By lectures, newspaper articles, and books he sought to arouse public interest in the great possibilities for public good which lay in these "harvests of the seas."

His sense of honor and justice was highly developed and his indignation was aroused when any case of injustice or abuse of power came to his notice. In particular he respected the rights of servants and the poorly educated, and he resented any infringement of these rights. While at Nassau, a merchant of the town tried to compel Doctor Brooks to pay him the wages of a negro servant of the laboratory. Doctor Brooks refused to do this unjust act, as he regarded it, and he resisted all pressure which was brought to bear to compel him to do this, even at the risk of being unable to sail on the steamer on which he had engaged passage. With a sense of obligation, unusual and perhaps exaggerated, he held that the university which employed him was entitled to all that he might earn by outside work; fortunately for him his university recognized no such obligation.

He was occasionally very happy in the use of scriptural language, illustrations, and quotations. He acquired his familiarity with the Bible in his grandfather's family, where it was read daily His familiarity with the scriptures was often shown in his writings and conversation. On one occasion, in a discussion of Weismann's essay on "Life and Death," in which, as is well known, Weismann claims that death is not a necessary and primary characteristic of living things, but one

which has been acquired, one of the students asked whether such a view was not contrary to religious teaching. Professor Brooks at once replied: "As I remember it, St. Paul teaches that death was not an original corollary of life, for he says 'by sin came death.'"

His nature and cast of mind was strongly reverential, and he could be said to be religious in the higher sense, although he long ago ceased to attend church or to take any interest in the doings or affairs of religious bodies. A few years before his death he talked with the writer upon the subject of immortality, and maintained that faith in immortality was in no sense unscientific. His attitude on these things may be inferred from the following extracts from the "Foundations of Zoology":

If any believe they have evidence of a power outside nature to which both its origin and its maintenance from day to day are due, physical science tells them nothing inconsistent with this belief. If failure to find any sustaining virtue in matter and motion is evidence of an external sustaining power, physical science affords this evidence, but no one who admits this can hope to escape calumny; although it seems clear that the man of science is right, . . . for refusing to admit that he knows the laws of physical nature in any way except as observed order.

Many will, no doubt, receive with incredulity the assertion that the ultimate establishment of mechanical conceptions of life has no bearing, either positively or negatively, upon the validity of such beliefs as the doctrine of immortality, for example. The opinion that life may be deducible from the properties of protoplasm has, by almost universal consent, been held to involve the admission that the destruction of the living organism is, of *necessity*, the annihilation of life. Yet it seems clear that this deduction is utterly baseless and unscientific; . . . if it be admitted that we find in nature no reason why events should occur together except the fact that they do, is it not clear that we can give no reason why life and protoplasm should be associated except the fact that they are? And is it not equally clear that this is no reason why they may not exist separately?

During his first years at the Johns Hopkins University he and other members of the biological department boarded at "Brightside," on the shore of Lake Roland, seven miles from Baltimore. Here he met his future wife, Amelia Katharine Schultz, to whom he was married June 13, 1878. In after years Mrs. Posey, owner of "Brightside," bequeathed this

beautiful estate to her favorite niece, Mrs. Brooks Here Doctor Brooks and his family lived a happy life, with books, greenhouse, garden, and trees; and here Doctor and Mrs. Brooks entertained repeatedly the graduate students of the biological department. All of these students remember Doctor Brooks' devotion to Mrs. Brooks and the children. His interest in the education of his children and his pride in their achievements were so great that he not infrequently spoke of these things to his students, and his complete devotion to Mrs. Brooks was both touching and beautiful. For several years before her death Mrs. Brooks was an invalid, and Professor Brooks frequently spent days and nights at her bedside reading to her and attempting to ease her suffering, and no other work or duty was allowed to interfere with this service of love. Mrs. Brooks was a woman of simple and charming personality, and one of the most delightful memories which zoological students have of their life in Baltimore is of the pleasant evenings spent with Professor and Mrs. Brooks at their home, when biological classics were read and discussed, when the various biological expeditions were talked of, and in lighter vein, when the sayings of the children were told, the animal pets shown, and the home-grown orchids exhibited. No one who experienced it can ever forget the simple and cordial hospitality of Professor and Mrs Brooks, nor the sense of deep and abiding happiness which these glimpses of their home life gave.

Professor Brooks was a man of wide culture, though his absorption in his work was so great that many knew him only as a naturalist. He read widely, and wrote with much attention to his style. He knew well the world's best literature and art, and in his later years he found that he had a strong liking for music, especially the great compositions of Beethoven, Mozart, Wagner, and Bach.

One of his strongest characteristics was his judicial and philosophical temper. When he was once asked if he did not fear that someone would anticipate him in his great work on Salpa, on which he had worked for many years, he said: "I long since ceased to be troubled by such thoughts, for if another should publish on this or any other subject before I do, his work would probably be better or worse than mine. If it

was better, I should be glad to be saved the mortification of having published poorer work; if worse, it would only afford additional material for my paper." His mind was too large for little things, too sane for foolish ones He was remarkably original and suggestive in his methods of thought, and in his views of scientific, social, and philosophical problems he was as artless and direct as a child. He was critical, yet tolerant; modest, but dignified; loyal to his friends, his university, and his ideals; independent in thought and action, and not easily moved from a position he had once taken. He was kind and gentle; and neither in his publications nor in his relations with students did he ever deal in scorn, irony, nor invective. President Remsen said that he had been called the most lovable man in his faculty.

What is the secret of his remarkable influence over others, which his students and associates recognize? By general consent it is attributed not merely to his greatness as an investigator and teacher, but also to his character as a man. In his life there was nothing either to be concealed or explained. He was "a man in whom there was no guile;" a man of such transparent simplicity and sincerity, of such single-hearted devotion to science, so simple-minded, natural, kind, gentle, pure in thought and deed, that his *life* as well as his *work* has left an indelible impression upon all who knew him.

SICKNESS, DEATH, AND BURIAL.

A congenital defect of the heart had caused him to lead a less active life physically than do most men, and to this trouble other bodily ills were added as life advanced. He bore all these ills with fortitude and patience, and many of his friends did not know how serious his condition was. Professor Andrews, who was closely associated with him, says:

> In 1908 difficulty in breathing added to his burdens and his machinery was most seriously out of order He continued to come to his lectures and worked earnestly to complete a final paper on salpa, for which the drawings were finished and which he planned to write out in the summer This, he said, would probably be his last piece of serious microscopic research, since trouble with his eyes made the employment of immersion lenses too difficult; and his mind was eager to digest the facts of his long experience and the recent work of others But his strength

was not equal to the task. Sudden attacks confined him to his home, but yet his will brought him back to his laboratory, till one last day, February 12 After preparatory rest, driven by his conscientiousness, he forced himself to attend an oral examination of a candidate for the degree of Ph. D. Then walking to the train that brought him home, he was there overcome by a serious collapse. He was persuaded to go to the hospital and, after most severe attacks there, rallied; but in nine long months that followed he scarcely left his wheel-chair.

When he returned to his home he got such comfort as might be from the advent of spring, the passing of summer and the long lingering of autumn, amidst scenes so familiar and dear. Despite his critical state he was deeply interested in such news as came to him from the University. His last official act was a strong, successful plea for another when his own interests might well have absorbed his attention. His was real friendship growing out of his own wide sympathies.

While having some strength to correct the proofs of papers in press, he felt most keenly his inability to put his last work upon paper, and till this work was done he would not deem it right to retire or seek a pension.

Professor Brooks once told the writer of this memoir that he proposed to retire from his professorship when he had reached the age of sixty, and thereafter devote himself entirely to philosophical and scientific work. He reached the age of sixty in March, 1908, but how different was his realization from his plan. His retirement was not to the scholarly leisure for which he longed, but to pain, weakness, and mortal sickness. For nine months he struggled against a complication of organic heart trouble and kidney disease; he was unable to walk or lie down, but lived in a reclining chair. For a month before his death he was often in a semi-comatose condition, and for the last three or four days was unconscious The end came at last at sunrise on Thursday, November 12, 1908.

The autopsy revealed chronic diffuse nephritis, arteriosclerosis, congenital malformation of the heart with open septum ventriculorum, cardiac hypertrophy, atrophy of the olfactory lobes, and atrophy of the cerebral cortex. The heart was enormously enlarged, and with the opening in the septum between the two ventricles it is surprising that he lived as long as he did. He had for years expected death at any time, and at forty congratulated himself on having lived so much longer than any one acquainted with his condition could have expected. It is the opinion of experts that the explanation of his living to such

a comparatively good old age, was due to the fact that the heart lesion was very well guarded by muscular tissue, so that it did not increase during life. Had it been otherwise, it would have been out of the question for him to have survived so long.

His funeral was held on November 16th, at Towson, Maryland After preliminary services in Trinity Church, his body was followed by his colleagues, students, and friends to its last resting place "on the brow of a hill overlooking a broad valley, in the cemetery of the county seat of Baltimore county."

A meeting commemorative of Professor Brooks was held at McCoy Hall, Johns Hopkins University, on Sunday afternoon, December 6, 1908. President Remsen presided, and spoke of Doctor Brooks' early connection with the university, and of his career as an investigator, a teacher, a colleague, and a man. Addresses were delivered by Prof. B L Gildersleeve, Dr. H. M. Hurd, Prof. W. H. Howell, Prof. E. A. Andrews, and Dr. Caswell Grave. These addresses, together with a letter from Prof. William Hand Browne, and a biographical sketch of Professor Brooks by Doctor Andrews, were published in the Johns Hopkins University Circular for January, 1909.

A memorial dinner, attended by former students and biological associates of Professor Brooks, was held in McCoy Hall, Johns Hopkins University, on the evening of December 31, 1908. About sixty persons were present, and short addresses were made by Profs. S. F. Clarke, of Williams College; E. A. Birge, of the University of Wisconsin; E. B. Wilson and T. H. Morgan, of Columbia University; H. W. Conn, of Wesleyan University; H. H Donaldson, of the Wistar Institute; C. F. Hodge, of Clark University; F. H. Herrick, of Western Reserve University; M. M. Metcalf, of Oberlin College; J. P. McMurrich, of the University of Toronto; H. V. Wilson, of the University of North Carolina; R. G. Harrison, of Yale University; E. G. Conklin, of Princeton University, and W. H. Howell and E. A. Andrews, of Johns Hopkins University.

At this dinner it was decided to publish a memorial volume to Professor Brooks, to consist in the main of original scientific papers contributed by his pupils. Since Doctor Brooks was one of the editors of the Journal of Experimental Zoology,

it was decided to publish this memorial as a volume in that series; and it is now in course of preparation. In what better way may the memory of a great scientist and teacher be honored than by carrying forward the torch which has fallen from his hand?

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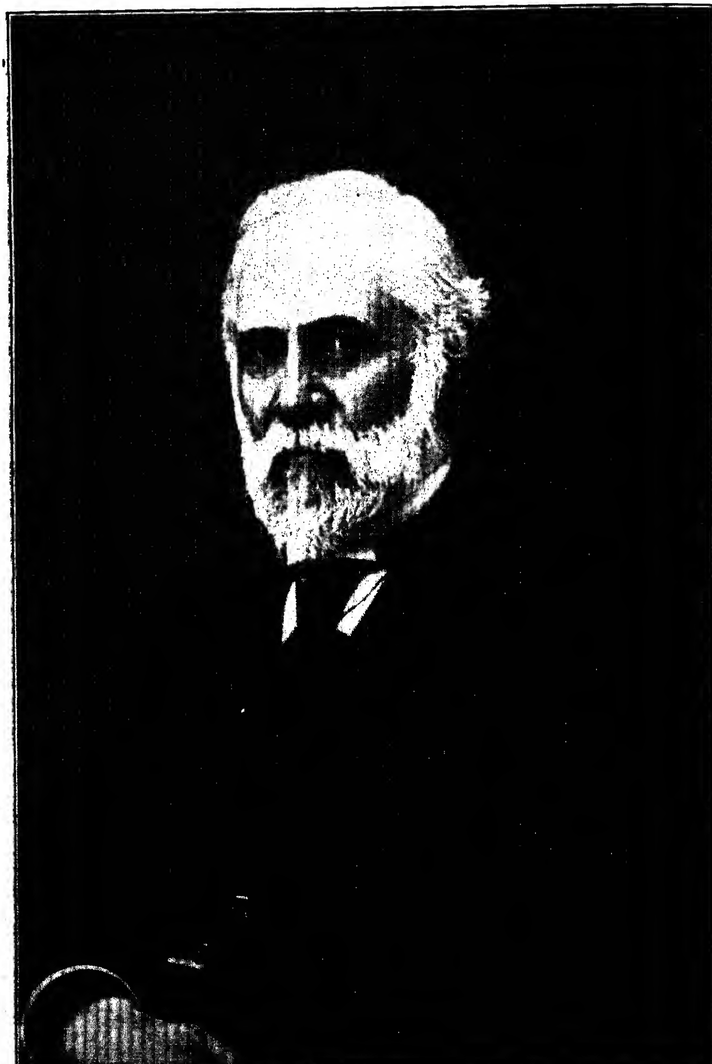

Yours Sincerely
C. A. Young

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BIOGRAPHICAL MEMOIR

OF

CHARLES AUGUSTUS YOUNG

1834-1908

BY

EDWIN B. FROST

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CHARLES AUGUSTUS YOUNG.

Charles Augustus Young was born in Hanover, New Hampshire, the seat of Dartmouth College, on December 15, 1834, and he died seventy-three years later, on January 3, 1908, in the same village, which had thrice been his home—in youth, in early manhood, and after his retirement from active work An academic career was his by inheritance, for his maternal grandfather, Ebenezer Adams, of New Hampshire origin, was professor of mathematics and natural philosophy at Dartmouth from 1810 to 1833, and was succeeded in that chair by his son-in-law, Ira Young, father of Charles Augustus. Ira Young was also from New Hampshire, having been born at Lebanon, five miles from the college, in 1801. He was prevented by circumstances from entering college until after he was of age but he took high rank and graduated in 1828, returning to the college two years later as tutor, and then assuming the duties of professor in 1833. Five years later his chair was changed to that of natural philosophy and astronomy, and it was filled by him with distinguished success until he died, in 1858. He was survived for thirty years by his widow, Eliza Adams, a woman of strong character and intellect.

Charles Augustus thus grew up in the atmosphere of natural philosophy, and, gifted with an active mind, he was ready for college before he had reached his fourteenth birthday; but it was thought best by his father that he should delay his entrance for a year. He graduated in the summer of 1853, at eighteen and a half years, the leader of a class of about fifty men From his early youth he assisted his father in some of his scientific duties, and made with him a trip to Europe in the summer of 1853, when the elder Young went abroad to examine foreign observatories and to secure instruments for the Shattuck Observatory, then in process of establishment, largely through his own efforts. For two years after graduation Charles taught the classics in the well-known preparatory

school, Phillips Academy, at Andover, Massachusetts During the next year he studied in the theological seminary at Andover, in accordance with an early plan to become a missionary; for a part of the year he continued his instruction in the classics at the academy. His later writings show that this training in the classics stood him in good stead.

An invitation to become professor of mathematics, natural philosophy, and astronomy at the Western Reserve College, at Hudson, Ohio, now changed his career, fortunately for science He entered upon the numerous duties of his new position at the beginning of 1857, and for nine years devoted himself to this work of teaching, with little opportunity and presumably with little apparatus for research. He established a time-service for the neighboring city of Cleveland, but it does not appear that he made astronomical observations to any considerable extent During several summer vacations at this time he acted as astronomical assistant on the Government's lake survey, being chiefly engaged in telegraphic determinations of longitude.

In the summer of 1857, shortly after he began his work at Hudson, he was married at Concord, New Hampshire, to Miss Augusta S. Mixer. She was a woman of unusually gentle disposition and character, understanding well how to enliven her husband when he was depressed with his many cares and responsibilities. This singularly happy union continued for nearly forty-four years, until broken by her death in 1901. Their children, a daughter and two sons, were born while they lived at Hudson.

In 1862 he left his college duties, in prompt response to the call of the Governor of Ohio for volunteers, and was for four months captain in the 85th regiment of Ohio, his company, B, being chiefly constituted from the students of the college. The company did not see actual service in battle, but was detailed to duty in guarding prisoners, and later escorted a large number of prisoners to Vicksburg to be exchanged. Professor Young's health was somewhat impaired by these patriotic services.

In February, 1866, he accepted the call to the professorship of natural philosophy and astronomy at Dartmouth, thus succeeding his father after a lapse of eight years. This particular

chair had been sufficiently endowed so that quite a large collection of apparatus, particularly in optics, had been acquired for lecture use Fortunately for the teacher, the method of laboratory instruction had not at that time been introduced in America; otherwise he could hardly have found time for the researches which marked the next few years, and established his position as a leader in the rapidly developing branch of solar physics.

His published writings on this topic began, so far as known, with a series entitled "Spectroscopic Notes," published in the Journal of the Franklin Institute, the first of which was dated July 19, 1869. He was provided with a spectroscope having five prisms of 45° attached to a four-inch telescope equatorially mounted. With this he carefully studied the spectrum of the chromosphere, and watched with a natural interest the strange forms of the prominences, the method for observing which had been simultaneously announced by Lockyer and by Janssen only in the year preceding. These spectroscopic notes were eight in number, the last dated November, 1870. They are brief and to the point. The second recorded drawings of the prominences, and the third was accompanied by a quite satisfactory lithographic reproduction of ten sketches, which have since been widely copied. He refers in the second to his first observation of the bright lines of the chromosphere extending in upon the disk. In the fourth he describes his first study of the spectrum of a sun-spot, finding the *C* and *F* lines reversed and many lines widened, as had been recorded by Lockyer. Young expresses his surprise at the prominence of the lines of titanium in the spot spectrum, which was also true of certain calcium lines. On September 22, 1870, he saw the sodium lines D_1 and D_2 reversed in the umbral spectrum. He adds,

> "At the same time the *C* and *F* lines were also reversed, but with the great dispersive power of my new spectroscope I see this so often in the solar spots that it has ceased to be remarkable"

Two days after he sent this communication to the editor of the Journal of the Franklin Institute, he wrote again announcing his success in obtaining a photograph of protuberances on the

sun's limb, using "the hydrogen line near G" ($H\gamma$). A woodcut was made from the photograph, but, with the modesty which was always characteristic of him, he says:

"As a picture the little thing amounts to nothing because the unsteadiness of the air and the maladjustment of the polar axis of the equatorial caused the image to shift its place slightly during the long exposure of three and a half minutes which was required, thus destroying all the details. Still, the double-headed form of the prominence is evident, and the possibility of taking such photographs is established"

This was the first photograph of a prominence obtained anywhere, and it prepared the way for the developments which have made the photography of the prominences a daily routine at observatories concerned with the sun.

He describes in his fifth note the new form of spectroscope he designed for solar work, having the dispersive power of thirteen prisms, the light passing first through the lower portion, and then back through the upper portion of a train of six prisms. The apparatus was made by Alvan Clark and Sons, and Professor Young expresses his admiration "for the exquisite workmanship of the 43 different surfaces by which the light is either refracted or reflected on its way from the slit of the collimator to the eye." The writer can add his testimony to the delight in the use of the same instrument, practically unchanged, nearly twenty years later, and it is still of excellent service despite the improvements of spectroscopes with the general application of the diffraction grating.

His final spectroscopic note gives in a dozen pages an admirable statement "on the construction, arrangement and best proportions of the instrument with reference to its efficiency." The advantages of using a half-prism at the beginning of a train is pointed out, and a simple form of chemical spectroscope is proposed in which flint half-prisms are cemented directly to the single crown lenses of collimator and observing telescopes, the back surface of the prism being made concave to fit the lens. The plan is a very good one and has recently been applied in celestial spectroscopes.

With keen interest in the study of the chromosphere and prominences, stimulated and made possible by the far-reaching results of the spectroscopic observations of the solar eclipse

of 1868, it was natural that Young should wish to observe the eclipse of August 7, 1869. He became a member of the party organized by the U. S. Naval Observatory, under the charge of Professor J. H. C. Coffin, of the Nautical Almanac Office. The station was at Burlington, Iowa, and was favored by fine weather, so that excellent results were secured. An interesting popular account of this eclipse was contributed by Professor Young to "The Dartmouth," the students' paper, for September. His scientific discussion was printed in Silliman's Journal for September, 1869, under the title, "On a new method of observing contacts at the sun's limb, and on other spectroscopic observations during the recent eclipse." Half an hour before totality he conceived the idea of observing the contact through the spectroscope set radially upon the sun's disk, and watching the bright *C* line shorten under the approach of the moon; he was gratified at the realization of his plan, and he felt confident that his observed time of contact must be accurate within a second. He suggested the application of the method to the case of the transit of Venus of 1874, for which preparations were already in mind. He later found that this proposal had been made to the French Academy by Faye in January of that year. Young examined during the totality the spectrum of prominences which he had located earlier in the day: *C* was brilliant, the next to it was "the orange line, which for convenience I will call D_3." Then he noted that the line 1474 *K* extended clear across the spectrum, and persisted when the slit was moved away from the protuberance. "Thus it was evident," he states, "that this line belonged, not to the spectrum of the protuberance, but to that of the corona." He also noted a faint continuous spectrum, without dark lines, "evidently due to the corona." The apparent coincidence of three coronal lines with lines located by Winlock in the spectrum of the aurora led Young to entertain the view that the phenomena of corona and aurora were related, with 1474 *K* in particular present in both. He did not assert the relationship with any positiveness, stating, "I do not feel in a position to urge it strongly, but rather await developments." Although he soon saw the error, it was long before it could be suppressed, after once gaining currency. There was much discussion as to the origin

of the characteristic corona line 1474 *K*, Lockyer regarding it as due to iron, Secchi as due to hydrogen. The matter was not really cleared up until the Indian eclipse of 1898, when both Lockyer and Campbell found that the wave-length of the corona line is actually a trifle less (λ 5304 on Rowland's scale) than 1474 *K* (λ 5317). The latter is, as Young found, a characteristic chromospheric line, and is probably due to iron.

In view of the interesting discoveries at this eclipse it is not surprising that a strong party of American observers, under Professor Winlock, including Professors Langley, Pickering, and Young, was prepared to study the phenomena of the eclipse of December 22, 1870, at Jerez, in Spain. Better favored than most other parties, they had a chance for observations at totality, through a break in the clouds Young's discovery of the 1474 line as due to the corona was fully confirmed; it was followed out beyond the limb a distance of more than half the solar radius, and it was seen to be the brightest of the lines Let us now quote from Young's own words:

"No new lines were observed with which I was not before familiar. But just at the commencement of the totality I made an observation, which was wonderfully beautiful to see, and which, I think, has important theoretical bearings The slit of my spectroscope was placed tangential to the sun's limb, just at the base of the chromosphere, the 1474 line on the cross-wires As the crescent of the sun (or decrescent, rather) grew narrower, this line, and the magnesium lines close by, as well as some others in the same neighborhood which I am accustomed to see bright in prominences, gradually increased in brilliancy, when suddenly, as the last ray of the solar photosphere was stopped out by the moon, the whole field of view was filled with countless bright lines—every single dark line of the ordinary spectrum, so far as I could judge in a moment, was reversed, and continued so for perhaps a second and a half, when they faded out, leaving only those I had at first been watching. This points to an atmosphere of heated vapor some five or six hundred miles in thickness above the photosphere, and tends to make Kirchhoff's original theory of the constitution of the solar surface again tenable."

This is from his interesting account of the eclipse written on the next day for the college paper, "The Dartmouth," to which he had previously contributed an exceedingly readable narration of his visits en route at Gibraltar and Tangier. In his letter to Professor Morton for the Journal of the Franklin

Institute, also written on December 23, he states his discovery of the reversing layer very clearly:

"But the most interesting spectroscopic observation of the eclipse appears to me to be the ascertaining, at the base of the chromosphere, and, of course, in immediate contact with the photosphere, of a thin layer, in whose spectrum *the dark lines of the ordinary solar spectrum are all reversed.*"

The phenomenon was also seen, for an instant only, by Mr. Pye, a young Englishman, who assisted Professor Young, using one of his spectroscopes.

The objective reality of this phenomenon was not fully confirmed until Mr. Shackleton, of Sir Norman Lockyer's party at Nova Zembla, a quarter of a century later, obtained the first successful photograph of the "flash spectrum" at the eclipse of August 9, 1896 Since then it has been photographed by many observers at most of the eclipses favored with clear skies.

The problem of the solar corona occupied Professor Young's mind for some time after the eclipse, and in May, 1871, he published in the American Journal of Science a paper "On the solar corona," supplemented by a note on its spectrum in the July number. After the lapse of nearly forty years there is little to be added to his presentation of the complex nature of the spectrum and the probable sources of its constituents.

In 1870 Professor Young was a member of the Board of Visitors to the U. S. Military Academy at West Point, and, as secretary of the board, wrote its report to the Secretary of War.

A lecture delivered by Professor Young before the Yale Scientific Club, on "The sun and the phenomena of its atmosphere," was published as a booklet in duodecimo form of 55 pages in 1872. It probably was not widely circulated, but it formed the basis of his classic, "The Sun," of the International Scientific Series, which appeared in 1881.

His observational activities were still chiefly directed to the sun, although he printed in The American Journal of Science, in 1870, an account of "a new method of determining the level-error of the axis of a meridian instrument"; and of observations of the spectrum of Encke's comet, which was faintly visible to the naked eye in December, 1871. At this time he

had a 9.4-inch Clark equatorial for his work. The observations of the cometary spectrum were consistent and reliable, and could hardly be improved upon today with the same telescope and the visual method.

Four weeks of work in the autumn of 1871, nearly at the time of a solar maximum, sufficed for a preliminary catalogue of the bright lines he saw in the spectrum of the chromosphere, 103 in number He called attention to the presence of titanium lines, which constituted one-fifth of the whole number reversed The advantage of a high elevation, with diminished reflection from our atmosphere, was apparent, and in the summer of 1872 Professor Young, under the auspices of the U. S. Coast Survey, made an expedition to Sherman, Wyoming, on a high plateau about 8,300 feet above sea-level, where he set up his telescope and spectroscope and added 170 to his list of chromospheric lines. He states that the elevation gave

"even greater advantages for my special work than had really been expected, although I was never quite able to realize my *hope* of seeing all the Fraunhofer lines reversed, unless once or twice for a moment, during some unusual disturbances of the solar surface Everything I saw, however, confirmed my belief that the origin of the dark lines is at the base of the chromosphere, and that the ability to see them all reversed at any moment depends merely upon instrumental power and atmospheric conditions " *

An observation very important in its bearing upon the future development of the study of the surface of the sun is mentioned at the end of this brief paper. Referring to the fact that the calcium lines H and K were both reversed, as constantly as h or C when the seeing was good, he adds:

"They were also found to be regularly reversed upon the body of the sun itself, in the *penumbra and immediate neighborhood of every important spot.*" (Italics his)

Professor Young made a comparison of the solar outbursts observed at Sherman with the magnetic records at Greenwich and Stonyhurst, and regarded it as probable that every solar

* This has now been practically realized at the Mt. Wilson Solar Observatory. See the paper by Hale and Adams entitled "Photography of the 'flash' spectrum without an eclipse," *Astrophysical Journal,* Vol. XXX, 1909 (October), p. 222.

disturbance receives an immediate response from the earth, and that the magnetic impulse travels, sensibly, with the velocity of light. It is surprising that this question is still under discussion after every case of marked "earth currents" or an extra brilliant aurora: the probabilities are perhaps as much in accord with Young's view as ever.

The coming transit of Venus was now exciting the interest of astronomers. Professor Young was asked to take charge of a party to be stationed at Kerguelen Island, but was unable to leave his teaching for the necessary length of time. He did, however, join the party under Prof. J. C. Watson at Peking, which secured results satisfactory at the time, before the comparative futility of that mode of determining the sun's distance was appreciated.

At about this time Professor Young contributed semi-popular articles on solar phenomena to the Popular Science Monthly and other serious reviews, and wrote for Johnson's Cyclopædia the articles on "Sun" and "Spectroscope." It must be remembered that during all of these years at Dartmouth he was teaching physics as well as astronomy to every third-year student in the college, and was giving annual courses of lectures at two or more schools for young women, besides many popular addresses.

He had promptly appreciated the advantages of the diffraction grating when he saw those ruled by Rutherford, who later placed some at his disposal. He then detected the duplicity of the 1474 line, thus apparently clearing up the outstanding difficulty as to the origin of the corona line, which he never could accept as an iron line. In the summer of 1876, with a good grating, he applied Doppler's principle to the rotation of the sun, and obtained the first good quantitative results by the method.* He hoped to use the atmospheric lines as reference points, but found those he tried "too faint and shadowy;" he therefore set his wires alternately upon the east and west limbs of the sun, and measured the differences, obtaining for the velocity of the sun's rotation 1.42 miles per second, while the value derived from observations of sun-spots was 1.25.

*Vogel had sucessfully made the experiment in 1871 with small dispersion, but his results could not be very accurate quantitatively

In the summer of 1877 Professor Young accepted a call to the professorship of astronomy at Princeton, with the assurance of a fine modern equipment and less time required for the class-room. His special appreciation of instruments and his well-balanced judgment as a teacher contributed to the establishment within a short time of the best astronomical observatory for the purposes of instruction then existing. By 1882 the excellent 23-inch Clark refractor was set up in the Halsted observatory, and provided with a powerful solar spectroscope for his own researches. But in spite of the energy necessarily required for this new construction, Professor Young was active in research as well as writing. In 1878 he conducted a Princeton party to Denver to observe the eclipse of July 29. It was the plan to investigate the spectrum of the corona and chromosphere, especially in the infra-red and ultra-violet, but the results, at this time of minimum solar activity, were less than had been expected, although the day was fine; the corona line and others were far less conspicuous than at eclipses during a solar maximum.

In the following year he made quite an extensive series of micrometric measures of the polar and equatorial diameters of Mars, using the excellent 9½-inch equatorial; the satellites were frequently seen with that instrument. Cometary spectra were also observed as they presented themselves in sufficient brightness, including Brorsen's (1879), Hartwig's (1880), and the great comets of 1881 and 1882.

The latitude and longitude of the students' observatory were carefully determined at about this time.

Professor Young contributed a number of admirable essays to the Princeton Review, having for their topics "The Recent Solar Eclipse," "Recent Progress in Solar Astronomy," "Practical Uses of Electricity," "Astronomical Facts and Fancies for Philosophical Thinkers," the last a lecture delivered before the Summer School of Christian Philosophy. All of these deserved a wider circulation than they probably received.

An extended program for the transit of Venus on December 6, 1882, was carried out under somewhat unfavorable conditions at Princeton, micrometric, spectroscopic, and photographic observations being included.

Professor Young contributed to the American Journal of Science two further papers, entitled "Spectroscopic Notes," in November, 1880, and November, 1883. Though brief, they are important The first deals with the *H* line in the chromosphere; with the successful resolution of lines given on maps as common to two different elements ("basic lines"); with the distortion of solar prominences in a diffraction grating spectroscope, and deriving the formula therefor; he adds a note on an immense prominence, over 350,000 miles high The second paper gives results with a powerful spectroscope of the Littrow type attached to the 23-inch telescope, whereby he resolved "the spot spectrum into a congeries of fine (dark) lines," an observation which has been fully confirmed with yet more powerful apparatus.

In 1892, when the Halsted Observatory received its new spectroscope by Brashear with a fine Rowland grating, Professor Young undertook the work of revising his list of chromospheric lines. Ill health and other causes delayed the work, so that it was never entirely completed, but it was published as "a partial revision" in 1894 in the edition in English of Scheiner's "Astronomical Spectroscopy." This was his last extensive piece of observational work on the sun. His other observations with the 23-inch telescope dealt with the planets, with certain double stars, and with the spectrum of *Nova Aurigæ*. He had at this time some exchange of opinion with a prominent English observer on the subject of large versus small telescopes. Admitting as "sadly true" the greater susceptibility of large instruments to atmospheric disturbances, he finds it also true—

"that I can almost always see with the 23-inch everything I can see with the 9½-inch under the same atmospheric conditions, and see it better—if the seeing is bad, only a little better, if good, immensely better . . Under higher powers, also, markings which are conspicuous with lower ones often disappear in the same way that the naked-eye markings on the moon vanish in the telescope. Most commonly, however, when I have failed to see with the large instrument anything I supposed I saw with the smaller, it has turned out on examination that the larger instrument was right, and that imagination had constructed a story that was not true, by building up faintly visible details and hazy suggestions furnished by the smaller lens."

A beginning was made in stellar spectrographic work with the new instrument, using both a grating and prisms, but attacks of sciatica had reduced Professor Young's capacity for prolonged night work, and the lack of a regular research assistant at the Halsted Observatory prevented a continuance of investigations in the field.

Solar eclipses very naturally retained his interest and he was enabled by the generosity of friends to take a small party to Russia for the eclipse of August 19, 1887. The station selected by Professor Struve for this party was not very far from Moscow, but, like most other points along the track of totality, it suffered from very bad weather, and no observations were possible. However, the trip gave Professor Young an opportunity to visit the leading observatories of Europe, renewing many friendships and establishing new ones, and he gave a very interesting account of it in Scribner's Magazine for July, 1888, under the caption, "An astronomer's summer trip."

At the eclipse of May 28, 1900, Professor Young organized quite a large party from Princeton and established a station at Wadesboro, North Carolina. The weather was very favorable and excellent results were obtained, but the corona line was too faint for carrying out the program Professor Young had prepared.

During these years Professor Young was delivering many addresses, and he always took such responsibilities very seriously—unnecessarily so, indeed, in later life. A lecture upon a topic somewhat out of his regular line would often lie heavily upon him for weeks until satisfactorily worked out. His address as vice-president of Section A at the Buffalo meeting of the American Association for the Advancement of Science, in 1876, was upon the topic "American Astronomy: its history, present state, needs, and prospects"; as retiring president of the association, at the Philadelphia meeting, in 1884, he discussed "Pending Problems in Astronomy" in a masterly fashion.

He felt no shame in accurately popularizing science, and responded frequently to the requests of the editors of the magazines. To the North American Review he contributed articles upon such topics as "Astronomical collisions," "Theories re-

garding the sun's corona," "The newest telescope"; to the Forum, "College athletic sports," "Great telescopes," "The latest astronomical news." He summarized the advances from 1876 to 1886 in "Ten years' progress in astronomy," read before the New York Academy of Sciences. He delivered the principal address at the dedication of the Kenwood Observatory, at Chicago, in 1891. He contributed many brief notes to the New York Independent, and wrote many reviews for that weekly and for The Critic He also occasionally wrote at the request of the editors of New York newspapers, which did not at that time crave sensational articles so much as now. Probably the financial stress, so familiar (and perhaps ultimately beneficial) in the experience of college teachers, was also a partial motive for some of these contributions.

He contributed for Professor Newcomb's admirable "Popular Astronomy" a statement of his views upon the constitution of the sun, and, at the request of Professor Vogel, editor of the third German edition of that work, he revised that statement to correspond with the increase of our knowledge up to 1904. This was also printed in English in the magazine "Popular Astronomy."

In 1884, in conjunction with Prof. E. C. Pickering, he edited for the Proceedings of the American Academy of Arts and Sciences the researches of the late Dr. Henry Draper on astronomical spectrum-photography.

Professor Young's reputation as an author, already well established by his many semi-popular articles, was widened still more on the appearance, in 1881, of his book, "The Sun," which at once took a commanding place among works of its class. While it is a volume constantly needed by specialists in solar physics, it is written in such a simple and interesting manner as to attract and hold the intelligent general reader. It has passed through several editions, and has been translated into foreign languages.

His rare experience as a teacher was finally crystallized in his "General Astronomy," which appeared in 1888, and was widely adopted in college use. It emphasized one of his fundamental pedagogical principles, that the things taught "must be correct and accurate as far as they go." It contains ideas sug-

gestive to the investigator, as well as teacher and student, and did much to encourage accurate thinking on the part of pupils who have studied it. The successive issues of the book were altered and enlarged by notes until a revised edition was necessary in 1898. Nearly 30,000 copies of this work have been printed. It called, however, for some rather difficult thinking for students not specializing in science, and a more elementary book, entitled "The Elements of Astronomy" (with Uranography), appeared shortly thereafter and was used still more widely in schools and colleges. Responding to the demand for a work available for quite young pupils, the "Lessons in Astronomy" appeared in 1891, and over 60,000 copies have been sold. A text-book intermediate between the "General Astronomy" and the "Elements" was called for, and was issued in 1902 under the title of "Manual of Astronomy." It was a handsomer book than the "General" and omits little of importance that is contained in the latter. An edition, revised by his niece, Miss Anne S. Young, professor of astronomy in Mount Holyoke College, is now appearing.

The very considerable labor involved in the preparation of these text-books was not given at the expense of research, as the condition of his health had prevented him from much observing after the early nineties. By a strict regimen he kept in check the inroads of a very serious disease, from which his physician could pronounce him as practically recovered only a very short time before his death.

His influence as a teacher was greatly widened by the large use of his text-books, and the position of authority which they gave him carried with it the burden of an increasing correspondence and the answering of many queries from all sorts of readers. He was also consulted very generally by teachers planning new equipment, by young men undertaking spectroscopic work, and by the many who valued his scientific and educational experience.

Upon the establishment, in 1895, of the Astrophysical Journal he became a member of its advisory board, known at first as associate editors, later as collaborators, and he retained this connection until his death.

Insufficient allusion has been made to Professor Young's ap-

preciation for and skill in mechanical matters. He devised an improved clock escapement which has performed satisfactorily for many years at Princeton, and a suggestion of his is incorporated in most of the conical pendulum driving clocks in use in this country. In practical astronomy he would have made more contributions had his time not been occupied with solar physics; but he proposed a method of investigating pivot errors, detected the serious effect of flexure in the "broken transit," and showed how it could be corrected, and investigated in his own way the color-correction of achromatic object-glasses. He also wrote on such physical topics as "Mr Edison's dynamometer, dynamo-machine, and lamp," and he kept abreast with the new discoveries of physics and related branches of science

Professor Young's personal characteristics were so obvious that it is hardly necessary to allude to them in addressing his contemporaries in the National Academy, to those who have missed the great opportunity of knowing him, it may be said that he was thoroughly infused with the true scientific spirit—ever ready to modify theory to accord with newly discovered facts, and to accept the revision of what were once the best data available as new information was obtained by experiment and observation. He was entirely free from the dogmatism that often grows upon men after they have long been looked up to as authorities upon a subject. His modesty, even humility, in the consideration of the great laws of nature was a true characteristic of his greatness. This impressed itself upon his thousands of students and upon the many auditors at his lectures. As a teacher, his methods and manner were simple and straightforward; his remarks were enlivened by a quaint humor which also pervades his writings. He took a genuine interest in his pupils, and it was remarkable how quickly he learned and retained the names of the members of the large classes which always attended his courses, attracted probably less by the subject than by the teacher, who was affectionately nicknamed "Twinkle."

Professor Young was small of stature, growing a trifle stout in later life; he was not especially fond of physical exercise and had no hobbies in the way of recreation, but he took a real interest in college sports. The writer has a very distinct men-

tal picture of him in the early seventies, playing on his well-kept lawn the then popular game of croquet, for which several of his colleagues regularly gathered. He always aimed at skill in whatever he undertook. At Princeton he found recreation in whist, playing a good hand of an occasional evening.

The life in his home was ideal, and its gentle courtesy is remembered by the many who were welcomed to its cheer. Astronomers from foreign countries, traveling in America, always included a visit to Princeton in their itinerary when possible, of course far more to see the man than the excellent observatories under his charge

Mrs. Young was a singularly attractive woman, who playfully diverted her husband's mind from his work when he was off duty, and by her devotion to him and attention to household details, gave him the opportunity for performing his many duties with as little disturbance as possible. Her failing health greatly depressed him, and her death in 1901 was a blow from which he could not recover. Other serious anxieties and sorrows came to him before this: the dangerous accident to his oldest son from an electric shock, causing paralysis from which recovery was long doubtful and never complete; the death of his daughter's husband, Prof. Hiram A. Hitchcock, of Dartmouth, after a short married life.

Upon reaching the age of seventy, in December, 1904, Professor Young sent to the trustees of Princeton his resignation, to be effective in the following June, when his service of twenty-eight years would be completed. Evidences of appreciation of his long and useful service, and of his own personality, came to him from all directions during the remainder of the academic year, and brought much quiet satisfaction to him. He was made professor emeritus, and also came under the provisions of the retirement fund of the Carnegie Foundation.

A farewell dinner, which brought out in a striking manner the unusual feeling of regard toward him on the part of his colleagues and the university authorities, was given him on May 17, 1905, and a handsome silver loving cup was presented to him. At commencement, a month later, the degree of doctor of laws was conferred upon him at Princeton, with further expressions of deep feeling.

The poem in the New York Sun by Robert Bridges, a former pupil, gives the real spirit of his teaching:

"THE ASTRONOMER

The destined course of whirling worlds to trace,
To plot the highways of the universe,
And hear the morning stars their songs rehearse,
And find the wandering comet in its place
This was the triumph written in his face,
And in the gleaming eye that read the Sun
Like open book, and from the spectrum won
The secrets of immeasurable space!

But finer was his mission to impart
The joy of learning, the belief that law
Is but the shadow of the power he saw
Alike in planet and in throbbing heart—
The hope that life breaks through material bars,
The faith in something that outlives the stars!"

He returned to his early home at Hanover, where his daughter, with her son, lived with him. The enfeebled condition of his health did not permit him to undertake much work, however, and he again was afflicted by the long illness and death of his daughter. During the last months of his life he was recovering from the Bright's disease which had beset him for years, and there was hope that he might have some period of health, but after a brief attack of pneumonia he died peacefully on January 3, 1908. He was survived by two sons, Charles Ira, of the Westinghouse Electric Company, and Frederick A., of the U. S Coast and Geodetic Survey, and by his grandson, Charles Young Hitchcock.

Many honors naturally came to him during his career. He was made associate of the American Academy of Arts and Sciences in 1869, of the Royal Astronomical Society in 1872, and later of the Philosophical Societies of Manchester and of Cambridge, England, and of the Società degli Spettroscopisti Italiani. He became a member of the National Academy of Sciences in 1872, and of the American Philosophical Society in the same year. He was made a foreign correspondent of the British Association for the Advancement of Science in 1887. In 1891 he received the Janssen medal of the French Academy

of Sciences for his spectroscopic researches. Honorary degrees were bestowed upon him liberally—that of doctor of philosophy by Pennsylvania in 1870, and by Hamilton in 1871; that of doctor of laws by Wesleyan in 1876, Columbia in 1887, Western Reserve in 1893, Dartmouth in 1903, and Princeton in 1905.

Throughout his whole life Professor Young retained the strong religious convictions of his youth: he was essentially a man of faith. There is an especial appropriateness in the inscription upon his tomb in the old cemetery at Hanover:

"For now we see through a glass, darkly; but then face to face."

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NOTE—The portrait accompanying this memoir was taken at Princeton in April, 1897, and is the original for Harrison's painting.

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Very truly Yours, B. Silliman

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VII

BIOGRAPHICAL MEMOIR

OF

BENJAMIN SILLIMAN

1816-1885

BY

ARTHUR W. WRIGHT

PRESENTED TO THE ACADEMY AT THE APRIL MEETING, 1911

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Of the biographical memoirs which are to be included in Volume VII, the following have been issued:

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BENJAMIN SILLIMAN.

Benjamin Silliman was born in New Haven, Connecticut, on the fourth of December, 1816, and died in that city on the fourteenth of January, 1885. He was most fortunate in his ancestry and the circumstances of his early life. His father was Benjamin Silliman, Yale College, 1796, who, as professor in Yale College, from his appointment in 1802 until his retirement in 1853, had held a foremost position in the institution, and whose name was one of the most illustrious in the history of American science. His grandfather, Gold Selleck Silliman, a graduate of Yale College in 1752, rendered distinguished service in the War of the Revolution in the defense of the southwestern portion of the State of Connecticut, and attained the rank of brigadier general. His great-grandfather, Ebenezer Silliman, also a graduate of Yale College, in the class of 1727, was an eminent lawyer, a judge of the superior court of the Colony, and a member of the governor's council. Of earlier ancestors in this country, the first, Daniel Silliman, settled in Fairfield, Connecticut, establishing his residence upon an eminence still known as Holland Hill, and probably so named from the country from which he is believed to have emigrated to America. The tradition of the family indicates for it an Italian origin, and this is supported by the testimony of families of the same name living in Switzerland and in southern France. Mr. Silliman's great-grandmother, whose maiden name was Rebecca Peabody, was a great-grand-daughter of John Alden and Priscilla Mullins, of the *Mayflower* and the Plymouth Colony. On his mother's side he was connected with a family which had been identified most conspicuously with the early history of the State and the strenuous times of the war of independence. His mother, a woman of great strength of character and beauty of person, was Harriet Trumbull, the daughter of Jonathan Trumbull, governor of the State of Connecticut from 1798 to 1809, who was the second of the name to bear this title, his father, Jonathan Trumbull, having been

the famous governor of the State during the Revolutionary War.

The elder Silliman, a man of imposing presence, of great dignity and nobility of character, was of a most hospitable spirit, which made his home a center of refined and cultivated social life, where the many distinguished men of science, who from time to time visited the city, were made cordially welcome. His son thus from the first enjoyed the advantages of a wide acquaintance with the leading spirits of the scientific world, and grew up in an atmosphere of scientific culture, the influence of which in determining the character of his own favorite studies was very great. He very early became interested in chemical experiments and in the collection of mineral specimens, and was laying the foundation for that intimate knowledge of the characteristics of mineral species, which eventually made him an expert in this department, with remarkable facility in the quick and sure recognition of new or interesting things.

He was prepared for college in the schools of New Haven, and in 1833 entered Yale College with the class of 1837, a class especially notable for the number of its members who rose to high distinction in after life. His favorite studies were not discontinued during his college course, and in 1836, during the months of August and September, with Mr. Eli Whitney, a New Haven friend, he accompanied his father on a professional visit to the gold mines and a portion of the gold region of Virginia, which afforded him opportunity for valuable observations. He had, at this time, already become a member of the Yale Natural History Society, of which he was later secretary and treasurer.

After graduating from college in 1837, with the exception of an interval which he spent in the private laboratory of Dr. Charles T. Jackson, the distinguished chemist, of Boston, he remained in New Haven, pursuing his studies in his father's laboratory, and for the next three years his name appeared in the catalogue of Yale College as assistant to the professor of chemistry. In 1840 he received the degree of master of arts, in course, and was made assistant in the departments of chemistry, mineralogy, and geology. In the next year the title was

changed to assistant and lecturer in the same departments, and he thus definitely entered upon his career as an instructor The situation remained unchanged until 1846, when he was made professor of chemistry and the kindred sciences as applied to the arts, his position being that of university professor.

During the winters of the four years 1840–1843 he had attended his father as his assistant in four courses of lectures on geology and chemistry, which were delivered at the Lowell Institute in Boston They were brilliantly illustrated with experimental demonstrations, and had remarkable success and popularity. His father gave grateful recognition of his devoted and invaluable service and the experience was a most profitable one for him and an important element in the training for his own life work.

During the years immediately after his graduation, while acting as assistant to his father and busily occupied in his laboratory, he had naturally taken up the work of teaching, and he very soon had gathered around him a little group of young men engaged in the study of chemistry, most of whom became distinguished teachers and investigators in after years and occupied positions of great influence in the advancement of science. Among these were John Pitkin Norton, a student of great promise, who was destined to come into closer relations with him later as a colleague, and Thomas Sterry Hunt, who became distinguished for his work in chemistry and chemical theory, and in mineralogy, and was a loyal and devoted friend throughout his life. The little school which had thus grown up through his influence had received no recognition from the authorities of the college and the names of its students were not enrolled in the college catalogue. In 1846, with the hope of securing for it a more firmly assured position, Mr. Silliman had drawn up a memorial, addressed to the corporation of the college, embodying a plan of organization and outline of a scheme of studies. This was warmly seconded by his father, and as a result of their efforts the corporation, in 1847, established a new and distinct department of the college, under the title of the "Department of philosophy and the arts," and in this year for the first time there appeared in the college catalogue a list of "Students in philosophy and the arts" number-

ing eleven. The first appointment in the new department was that of Mr. Silliman, who in the previous year had been made "Professor of chemistry and the kindred sciences as applied to the arts," as already mentioned. His position was that of a university professor, and he now became an active promoter of the new school, giving instruction in elementary and analytical chemistry, mineralogy, and metallurgy. With J. P. Norton, who had been appointed professor of agricultural chemistry and vegetable and animal physiology, he organized the "School of applied chemistry," and opened a laboratory upon the college grounds in an old wooden house which had formerly been occupied as a residence by the presidents of the college, and was thenceforth known as the analytical laboratory.

Although the school had been thus formally recognized and had attained to an established position, it received little other encouragement and no substantial aid from the college. Except for an annual income of three hundred dollars, which was provided for a few years by a generous friend upon the solicitation of Mr. Silliman, it was entirely without resources. The cost of fitting up and equipping the laboratory and for providing apparatus, cabinets, and library was furnished from the private means of the two professors, who received no salaries from the college and even for two years paid a rent for the use of the building. But their self-sacrifice and devotion were not in vain, for the school lived and prospered, and the spirit of its founders was perpetuated in their successors. Its establishment was the first and most important step in the development of the college into the university.

Professor Norton had recently returned from a visit abroad, during which he had spent some time in Edinburgh, where as a student with Prof. James F. W. Johnston, he had won a prize of fifty guineas, offered by the Highland Society, for his original researches upon the chemistry of the oat and the soil upon which it was grown. He was later at the University of Utrecht, where, under the eminent professor of chemistry, G. J. Mulder, he pursued studies in agricultural and physiological chemistry. He took up the duties of his new position with enthusiasm; was an energetic worker and a prolific writer.

Although naturally of a vigorous constitution, the burden of labor which he undertook proved too great for his strength, and he succumbed to pulmonary disease, closing his life in 1852 at the age of thirty years.

Among the earlier pupils of the Yale Scientific School, thus happily established as a recognized department of the college, were several who were later to become more closely identified with it as officers. The names of George J. Brush and William H. Brewer appear in the list of students in the department of philosophy and the arts for the first time in 1848, and that of Samuel W. Johnson in the following year. The two latter, after a few years, took up and carried on with distinguished success the labors of Norton in agriculture and agricultural chemistry, while the former, as professor, first, of metallurgy, and subsequently of mineralogy, and later as director of the school, as expanded by the munificent gifts of Mr. Sheffield, was associated with them in developing the Sheffield Scientific School to a position of great efficiency and influence.

After the death of Professor J. P. Norton the duties of his chair were discharged by John A. Porter, who had been appointed to the position as acting professor in 1852, and in the following year as professor of analytical and agricultural chemistry. In 1852, for the first time, the announcement of the department of philosophy and the arts in the college catalogue contained a list of the faculty of the department, which included, besides several names of professors in other departments, that of William A. Norton, professor of civil engineering. In the catalogue for 1854–1855 appeared for the first time the separate heading "Yale Scientific School," with the statement that the school was "under the immediate supervision of Professors William A. Norton, Benjamin Silliman, Jr., and John A. Porter," followed by a detailed account of the work of the school and the courses of instruction. The lectures in chemistry were given by Mr. Silliman, who, on the retirement of his father in 1853, had been made professor of general and applied chemistry, and who also from this time gave instruction in chemistry in the medical department of the college and lectures upon the same subject in the academical department.

During the year 1860 the school, by the liberality of Mr. Joseph E. Sheffield, had acquired a commodious building for its work and a generous addition to its funds for maintenance and instruction. In the following year the name Sheffield Scientific School was adopted, and it was enabled thenceforth to pursue a prosperous course, with enlarged resources and a faculty greatly increased in numbers. Mr. Silliman maintained his connection with the school until 1869, but for several years previous, owing to the multiplicity of engagements elsewhere, he had had little part in the work of instruction. He resigned his duties in the academical department of the college in 1870, but continued to give instruction in the medical department as long as he lived.

Mr. Silliman's activities were by no means confined to the class-room and laboratory, and throughout his life he was in sympathetic touch with movements of general public interest. He was a member of the common council of the city of New Haven from 1845 to 1849, was appointed State chemist of Connecticut in 1869, and for many years subsequent to 1848 was a director of the New Haven gas works and chairman of the committee on works and distribution. In 1853 he was active in connection with the Exhibition at the Crystal Palace in New York, where he was in charge of the departments of chemistry, mineralogy, and geology. As a result of this work he edited, in connection with Mr. Charles R. Goodrich, a large quarto volume entitled "The World of Science, Art, and Industry," which was published in 1853; and in 1854 Mr. Silliman published "The Progress of Science and Mechanism," a quarto volume of considerable size, the two works, which were profusely illustrated, constituting a valuable record of the most important results of the exhibition. In the winter of 1845-1846 he gave a course of public lectures in New Orleans upon agricultural chemistry, at the invitation of men of prominence in the professional and commercial circles of the city. This was doubtless pioneer work, as it is believed to be the first course of the kind delivered in the United States. Mr. Silliman was the secretary of his class, 1837, of Yale College, and issued several reports of the class meetings, with full biographical notices of the members, toward whom he always mani-

fested a warm interest and a cordial readiness for friendly service.

His early training in mineralogy and his interest in the subject had led to the acquisition of many mineral specimens, and he had thus gradually brought together a very valuable collection, which he disposed of in 1868 to Cornell University, where it has been on exhibition as the "Silliman Cabinet." From his many journeys made in connection with his mining and geological explorations he brought home numerous fine specimens, from which he made large contributions to the mineralogical cabinet of the college and the metallurgical collection of the Sheffield Scientific School. Through his personal efforts also funds were secured by means of which the mineralogical cabinet of Baron Lederer was acquired, in 1843, for the college collections.

In 1849 Mr. Silliman was elected professor of medical chemistry and toxicology in the medical department of the University of Louisville, Kentucky, and during five winters he discharged the duties of the position, taking up his residence in that city during the period of his professional labors. He resigned the position in 1854, to enter upon the enlarged duties of instruction in the college in New Haven, which fell to him in consequence of the retirement of his father. He had received the honorary degree of M D. in 1849 from the Medical College of the State of South Carolina. In 1884 the honorary degree of LL. D. was conferred upon him by Jefferson Medical College, of Pennsylvania.

In 1851 Mr. Silliman accompanied his father upon a visit to Europe. They left New York on the fifth of March, and the course of their travels, after their landing at Liverpool, took them through England and Wales, France, the Italian States, Lombardy, Switzerland, Germany, Belgium, and again France and England on their return. Although the route was not markedly unlike the customary one of ordinary travel, the purpose of it was very different. It brought them into regions interesting to the geologist and the mineralogist, with visits to the volcanoes of Vesuvius, Stromboli, and Etna, the Alps and the Jura Mountains, with the glacial regions, as well as to the most important laboratories, art museums, and scientific col-

lections of the countries traversed. Not less important were the opportunities they enjoyed of meeting distinguished men of science, by whom they were most cordially received. In England they met Dr. Mantell, already a friend of many years, and through his kindly offices were present at a meeting of the Geological Society at Somerset House. Here they met and heard in discussion Murchison, Lyell, Sir E. Forbes, Sir Henry de la Beche, and others known to them by reputation, and were warmly welcomed. In Paris they made the acquaintance of Adolphe Brogniart and Milne Edwards, attended lectures of Wurtz and Frémy, met Dufrénoy, Élie de Beaumont, Sénarmont, and Verneuille, through whose courtesy they were enabled to visit the Panthéon, where was in progress the celebrated experiment of Foucault, then a novelty, for giving ocular demonstration of the rotation of the earth by the motion of the pendulum. They were escorted to one of the weekly sittings of the French Academy by the venerable Cordier, who had accompanied Napoleon to Egypt. Here were present, besides most of those mentioned above, Biot, Arago, Boussingault, Payen, Dumas, Leverrier, and many others equally distinguished. In Geneva they made the acquaintance of Marignac, De la Rive, Favre, and Pictet. In Italy they had the pleasure of meeting Matteucci, Meneghini, and Melloni, who presented to Mr. Silliman a copy of his celebrated work upon Heat, of which, owing to the interruption of his labors by arbitrary official interference on political grounds, only the first volume was completed. Turning homeward, they visited the family of Professor Agassiz, then living at Lausanne: Professor Liebig at Giessen, and Leonhard and Braun at Heidelberg. In Berlin they were invited by the distinguished geographer, Carl Ritter, to attend one evening a meeting of the Geographical Society, of which he was the president. Here they met Ehrenberg, the brothers Rose, Dove, Magnus, Poggendorff, editor of the Annalen, and Mitscherlich, as well as many others well known to fame.

An interesting visit was made to Alexander von Humboldt, then in his eighty-third year, but still full of vigor and most cordial in his welcome. He pointed out, by the aid of his maps, a way of communication for an interoceanic canal across

the isthmus of Darien, which he had observed and described more than forty years before. Antwerp, Brussels, and the battlefield of Waterloo were visited in their further progress toward home, and they arrived in New York in the middle of September, after a journey full of profit and interest to both, and especially to the younger traveler, who had enjoyed it to the utmost. The elder Silliman had kept a full record of the events of the journey during their progress, and after their return this was edited by his son. It had been originally intended to fill three volumes, but had been considerably abridged, and was published in two volumes in 1856. It is still a very entertaining work, and full of most valuable information for those interested in the progress of science and the illustrious men by whom it has been achieved. Of the various scientific observations of interest made by him during the journey, accounts were published by the younger Silliman in the American Journal of Science on his return.

In his work as an instructor, in consonance with the terms of his professorship, the applications of science in the arts had always received particular attention. He was deeply interested in the practical developments of science and in making it serviceable to the general welfare. His knowledge in this field was remarkably comprehensive and accurate, and his retentive memory enabled him to have it at ready command. His aid was much sought for as an adviser in practical matters involving the application of scientific principles, and in the courts he was often called upon to give testimony in questions whose solution demanded technical skill and knowledge. He made many journeys for mineralogical and geological exploration and to examine and report upon mines. On one of these he left New Haven in March, 1864, returning in February of the following year, during which period the death of his father occurred, in November, 1864. He published in the American Journal of Science, 1866, an account of this journey, which extended to Arizona, the Mojave desert, and the San Francisco mining district. The visit was repeated in 1867, and again in 1872, and these and later trips covered a large part of the mining country of the Rocky Mountains. Numerous choice mineral specimens were acquired by him on these tours, of

which many ultimately found a place in the cabinets of the college.

The reports made by Mr. Silliman on the results of his professional labors, in the cases where he had been consulted, were very thorough and often grew into elaborate treatises. Though usually privately printed, they often contained scientific information which made them of permanent value, and which in numerous instances led to their reproduction in scientific journals Some of these are noted in the list of his scientific publications at the close of this memoir, but others are entitled to more extended consideration.

In a report, dated April 16, 1855, upon the rock oil, or petroleum, of Venango County, Pennsylvania, he described methods of investigation not hitherto employed and results which proved to be of signal importance and the first steps in the development of a great industry. Years afterward this was reproduced in the American Chemist, Vol. 2, 1871–1872, pp. 18–23, with the following editorial note:

> We have obtained of Prof Silliman permission to reproduce in this number of the American Chemist his original memoir on the Pennsylvania petroleum, written in April, 1855, as a report to the projectors of the first association ever formed for the purpose of developing this industry, since grown to such great proportions The report has never before been published in any scientific journal, although a few copies were privately printed at the time, and we deem it of too much historical and scientific interest not to be placed on our pages for the convenience of reference. At the time Prof. Silliman made this research, all that was known of the "rock oil" of Pennsylvania was that on the waters of Oil Creek, in Venango County, the oil oozed out in pits dug in the soil and floated on the surface of the water as a dark green dichroous oil of high density (882° B).* No artesian well then existed, or had been ever thought of as a possibility Drake's well was sunk more than two years after the report of Prof. Silliman was written. In reading this report now, after sixteen years of experience in the development of this important industry, we are struck with the fact that its author very nearly exhausted the subject, and anticipated and described most of the methods which have since been adopted by manufacturers. He even suggests the distillation by high steam, which has since been adopted with so much success by Merrill, in the preparation of his neutral heavy oil. He also noticed the peculiar breaking up of

* ".882, water being 1.000," in the Report. W.

the heavier oils into lighter products, under the continued action of heats far below their boiling points, now called "cracking" He remarks that when "exposed for many days in an open vessel at a regulated heat below 112°, the oil gradually rises in vapor, etc., gradually and slowly disappearing, and finally leaving a small dark and pitchy residue."

Prof. Silliman was the first to demonstrate by accurate photometric experiments the high value of the rectified oil as an illuminator, devising for that purpose an original form of photometer † in advance of Bunsen's instrument, employing for its consumption a lamp which is the prototype of the extensive progeny of kerosene lamps which have since that time been devised.

We reproduce the report of Prof. Silliman precisely as it was written, and it must, in justice to its author, be remembered that he then had no guide but his own sagacity in the conduct of this interesting research.

The observations made by him in the course of his work in connection with the wet-fuel litigation were the subject of an extended paper read before the American Association for the Advancement of Science, at the Newport session in 1860, which was published in the proceedings of that meeting and also reprinted elsewhere. A paper upon the chemical principles involved in combustion, published in the American Chemist in 1872, was another result of the same work. His chemical investigations in the service of the New Haven gas works furnished the material for several important papers upon the economies of gas-lighting and the illuminating power of coal gas as affected by varying conditions in combustion. His investigations upon the petroleum region of California led him to the conclusion that the geological conditions were such as to require a method of procedure for the extraction of the oil unlike that which had been employed in Pennsylvania, and he confidently expressed his belief that with the employment of suitable means, which were indicated by him, it would be produced in abundance. Although vehemently assailed, his conclusions have been most completely sustained by events and by the development of a great industry involving financial interests of vast extent.

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† For the description of this instrument, see American Journ. Sci., 2d ser., Vol. 23, 1857, p. 315.

The American Journal of Science had been established by the elder Silliman in the year 1818, and it at once took the rank as the leading American scientific journal, which it has continued to maintain. In 1838 his son, then in his twenty-second year, was associated with him as assistant editor, and in 1841 his name appears upon the title page as one of the editors, and this arrangement remained unchanged until the close of the first series of fifty volumes in 1845. In 1846 the editorial staff was increased by the accession of Prof. James D. Dana, and the responsibility of the editorial management was largely borne by the two younger men, although the name of the elder Silliman continued to head the list of editors until his death, in 1864. After this time the conduct of the journal devolved upon the younger Professor Silliman and Professor Dana, his brother-in-law, with the co-operation of a number of scientific men as associate editors. Mr. Silliman maintained his editorial connection with the journal until the close of his life, in 1885, thus completing a period of forty-seven years of unin terrupted service upon it. His contributions were very numerous, including, besides innumerable notes, reviews, and biographical notices, many original articles in which were embodied the results of his own investigations.

In one of his early papers, published in 1842, he described the successful production in the Yale laboratory of daguerreotype pictures by the light of the carbon arc for the first time. In this experiment the arc was produced by the current from the great battery of nine hundred pairs of plates, which had been constructed under the supervision of his father and had been employed by him for the brilliant demonstrations which illustrated his lectures. In the same year he published an interesting paper suggesting the use of carbon for the costly platinum in Grove's battery, and in a second paper upon this subject in the following year he described the construction and operation of a large battery of ninety-six cells built upon this plan. In this occurs the remark that the "form of carbon most efficient in voltaic circuits is that exceedingly hard and pure carbon which is deposited from coal gas on the heated inner surface of the retorts of the gasworks." The battery gave an arc in air about two inches in length. The use of gas carbon

for this purpose was an original discovery with him, and although he learned subsequently that he had been anticipated by others, who had made the discovery at nearly the same time as himself, but had announced it more promptly, there is little question that he was the first to use it in the actual construction of a battery of large size and to obtain such decisive evidence of its efficiency.

In 1847 he published a volume entitled "First Principles of Chemistry," which was very successful, passing through several editions and having a sale of more than fifty thousand copies. He also published, in 1859, "First Principles of Physics, or Natural Philosophy," of which a second edition was issued in 1861. The subject was treated in a fresh and original manner, and the volume contained much new and interesting matter. It was widely used as a text-book, the most successful one of its time.

In 1871, on the fourteenth day of September, Mr. Silliman delivered, as introductory to his course given to the medical class in Yale College, a most interesting lecture with the title "A century of medicine and chemistry." After a rapid review of the early history of medical science, he took up the subject of the discovery and application of various substances which had come into use as anesthetic agents, and of the physiological action of certain chemical compounds which had been employed in modern medical practice. The fondness for historical investigation displayed in this lecture was still more strikingly exemplified in an address on "American contributions to chemistry," which he delivered on the occasion of the celebration of the centennial of chemistry (dating from the discovery of oxygen by Priestley), which was held at Northumberland, Pennsylvania, on the first of August, 1874. This place of meeting had been selected because Priestley had resided there while in America. The address was published in the American Chemist in the latter part of the same year, much enlarged by the inclusion of a full list of the papers published by American workers in chemistry. This list, the preparation of which involved a great amount of labor and research, is itself a very valuable contribution to the history of chemical

science in this country. The complete work was separately issued as a volume of 176 pages, Philadelphia, 1874.

Mr. Silliman was one of the fifty original members named in the act of Congress of March 3, 1863, incorporating the National Academy of Sciences. He was a constant attendant of its sessions, and read before it many papers as contributions to its proceedings. He was a member of several important commissions of the Academy. In 1881 he was named as chairman of the commission on sorghum sugar, and prepared the voluminous report, the first draft of which was submitted to the Academy at the April meeting of the next year, and the completed report, of which the official copy was transmitted to the commissioner of agriculture in November, 1882. The printed copy covered 139 pages. At the meeting in Washington in 1884 he read a biographical memoir of his colleague, Dr. J. Lawrence Smith, which he had prepared by appointment of the Academy. It was a warm tribute to the character and scientific work of his friend, and included a very carefully prepared list of his publications. It was his last communication to the Academy, and this meeting was the last that he attended

Mr. Silliman was a member of many other scientific associations, among which may be mentioned the following: He was a corresponding member of the Meteorological Society of London; member of the Boston Society of Natural History, and of the Connecticut Academy of Arts and Sciences. He was a member of the Association of American Geologists and Naturalists from the second meeting, in 1841, and had been its secretary during several years. At the last meeting, in 1847, at which it was agreed to resolve the association into the American Association for the Advancement of Science, he was made a member of the standing committee. At the first meeting of the new association, in 1848, of which he thus became one of the original members, he was elected to the standing committee and the committee of publication, and was made secretary of the section of physics. He interested himself greatly in the success of the association, contributing numerous papers and taking an active part in the discussions. In 1864 he was elected life member of the California Academy of Sciences; in 1876, a member of the American Chemical Society; was

also associate fellow of the American Academy of Arts and Sciences, Boston, and corresponding member of the New York Academy of Sciences. He was elected a member, at its second annual meeting in 1872, of the American Institute of Mining Engineers, and in 1874 a corresponding member of the Société Nationale des Sciences, of Cherbourg, France.

In the preparation of his many published works Mr. Silliman was busily occupied during much of the time of his active life. When at home he would most usually be found at his library table, pen in hand, writing or correcting the proof of some fresh publication. He wrote rapidly, with fluent ease and with very few erasures or interlineations. If in the earlier years of his life this facility of utterance resulted in some degree of redundancy in vocabulary and expression, in his later writings this was less evident, and they are characterized by a style of marked individuality, of excellent literary quality, and a peculiar felicity in the choice of apt phrases for the expression of his ideas. They are clear, forcible, and withal interesting.

In person Mr. Silliman was of somewhat more than medium height, strongly and compactly built, with a massive head, indicative of intellectual power, and a countenance expressive of his sympathetic nature and genial social qualities. In manner he was dignified, but quite at ease, and with the power to put others at their ease in his society. His personal characteristics have been happily described in a sketch by Professor James D. Dana, published in the American Journal of Science, in February, 1885, soon after Mr. Silliman's death. Mr. Dana had been appointed by the National Academy of Sciences to prepare the memorial of his life and services, but did not live to accomplish it. The following passage appears near the close of the article:

Professor Silliman was a man of exceedingly generous nature and kindly disposition. He was ever cheerful, ever inclined to look upon the bright side of life, hopeful and sanguine of success where others might be discouraged; and if his expectations for himself and others were not always realized, it was largely owing to this element in his character. In society he was most genial, abounding in conversation based on a remarkable range of information on general topics and with anecdote ready for the entertainment of his guests. Hospitality to

friends of the college or to men of science or to those of his own kin and personal intimacy was his delight, and to this some of those present at the recent meeting of the British Association can testify.

During the greater part of his life Mr Silliman enjoyed excellent health. He had much more than the ordinary amount of vigor, and rarely felt the necessity of considering whether he were able to undertake any labor proposed to him or not Four years since, after an excursion, late in the autumn of 1880, among the mountains of Pennsylvania, he was prostrated for some weeks with heart disease; and it seemed to his friends for a while that at the best his days of active work were at an end. But in the course of another six months he was off to New Mexico on a visit to the Negretta Mountains (Black Range) in Socorro County; and he returned from the elevated mountain region apparently uninjured by the trip, though conscious of a weakened constitution. His energy was far from giving out, and other excursions were undertaken in the course of the following years, including another trip to New Mexico. His recent illness commenced in October last, with a severe return of his heart complaint, complicated by an attack of pneumonia; and from that time his decline made slow but steady progress—more visible to friends than to himself.

One of the last literary labors which he performed was the preparation, for the National Academy of Sciences, of a memoir of his old friend, Dr. J. Lawrence Smith, his successor at Louisville; and during the last few weeks of his life, when his strength was already largely gone, he gave directions, with a touching degree of affection and interest, for the completion of the medal which was to commemorate the labors of his academic associate. The generous, whole-souled affection for his friends, which characterized his entire life, was never more strongly manifested than during his last days.

In September, 1884, Mr. Silliman was present at the meeting of the American Institute of Mining Engineers in Philadelphia, and read an elaborate paper upon the Siemens improvements in glass-furnaces, with suggestions for their use with natural gas. This was published in the volume of the transactions of the institute for 1884–1885, and the secretary, in a note at the end of the paper, mentions the fact that Professor Silliman's death had occurred while the paper was in press, which prevented any revision of the proofs by him, and that it was probably his last work, the manuscript, which was mostly in his own hand, giving evidence of feebleness.

It was, indeed, his last work, and the steady progress of the disease soon compelled him to remain within doors and to forego active exertion of any kind. As the close of his life

drew near, his sufferings were very great, but he bore them with the most admirable fortitude and cheerfulness, until, on the evening of January 14, 1885, he passed away, surrounded by members of his family, for whom to the last he manifested the most affectionate solicitude.

Mr. Silliman was married on the fourteenth of May, 1840, to Susan Huldah Forbes, the eldest child of William Jehiel and Charlotte (Root) Forbes, of New Haven. She was a woman of rare beauty and personal charm, whose character and accomplishments served to make their household distinguished for its refined and gracious hospitality. She died, after a long illness, in March, 1878. Mr. Silliman was survived by an only son, of the same name, and four daughters.

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Very truly Yours,

J. Hammond Trumbull

"Káh wehquttum áhhutáusukwhôs-
imuk, kah wussukhum, nowau,
Owesuonk" (Luke 1.63)

J. H. Trumbull

Hartford, Conn.
Mch 15th 1870

Written by Dr. Trumbull in response to a request for something from the Indian Bible.

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VII

BIOGRAPHICAL MEMOIR

OF

JAMES HAMMOND TRUMBULL

1821-1897

BY

ARTHUR W. WRIGHT

PRESENTED TO THE ACADEMY AT THE APRIL MEETING, 1911

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NATIONAL ACADEMY OF SCIENCES.

Of the biographical memoirs which are to be included in Volume VII, the following have been issued:

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1911.

*

JAMES HAMMOND TRUMBULL.

James Hammond Trumbull was born in Stonington, Connecticut, December 20, 1821, the son of Hon. Gurdon and Sarah A. (Swan) Trumbull. His grandfather was John Trumbull, a kinsman of the first Governor Jonathan Trumbull, on whose invitation he removed from Massachusetts to Norwich, in the summer of 1773, to establish a weekly newspaper which should be the organ of the Sons of Liberty in the eastern part of the State. He edited and published the Norwich Packet from 1773 until the close of his life, in 1802. After his death his son Gurdon, with an elder brother, Henry, removed to Stonington, whither another brother, Samuel, had preceded him in 1798. The latter soon after began the issue of a newspaper with the title The Journal of the Times, which was changed later to The Impartial Journal. Henry was the author of a small volume giving an account of the settlement of the country and the conflicts with the Indians, and of some biographical narratives.

Gurdon Trumbull was a man of marked ability and force of character. The following estimate of him is from the pen of his son, the subject of this memoir:*

He was one of the band of volunteers who, in August, 1814, defended Stonington against a British squadron commanded by Sir Thomas Hardy. At the end of the war of 1812–14, he was established in business as a merchant, and began to take an active part in the development of the two branches of industry—the seal and whale fisheries—for which Stonington became distinguished, and from which her citizens for many years received large returns. He became a leader in town affairs and an efficient promoter of every enterprise that promised local or public benefit. He represented Stonington in the general assembly in 1840, 1848, and 1851; was a bank commissioner, 1839–40; and commissioner of the school fund, 1849–51. In 1852 he removed with his family to Hartford. He was an alderman of that city, 1854–55, in which years he served as one of the judges of the city court.

From early life Mr. Trumbull manifested an interest in historical and antiquarian studies. He read much, and until near the close of his

* New England Hist. Geneal. Reg., Vol. 39, 1885, pp. 288–289.

life, his memory was remarkably tenacious Of the history of his native county (New London), particularly, his knowledge was thorough, ready, and exact

The latter words are felicitously applicable to his distinguished son, who, reared in an atmosphere of antiquarian and historical learning, developed most naturally that spirit of zealous and painstaking research and precision of statement which he manifested so conspicuously throughout his life.

Gurdon Trumbull married, in 1816, Miss Sarah A. Swan, the only daughter of Capt. Thomas and Mrs. Fanny (Palmer) Swan. The latter was a descendant of Walter Palmer, one of the earliest settlers in Stonington, who had come there near the close of his life. His daughter, Grace, born in England about 1608, was the wife of Thomas Miner, another and prominent early settler of Stonington, whose grand-daughter, Grace Miner, became the wife of Samuel Grant, from whom was descended Gen. Ulysses S. Grant. Other notable families were related through the Swan and Palmer connection, among which were those of Hon. Nathan F. Dixon, an eminent member of the bar and a very prominent and influential citizen of Rhode Island, from which State he was elected a member of Congress for several terms, and his son of the same name, and equally distinguished, who served a full term as United States Senator from the same State.*

Of his childhood and early education the following passage from Dr F. B Dexter's admirable sketch furnishes interesting information.† He

was of frail health in childhood, and was much indoors in early life He was prepared for college at Tracy's Academy, in Norwich, Conn., and entered Yale in 1838, in his seventeenth year, but with mental attainments and capacities superior to those of most of his class. By the unusual range of his early reading also, and his exceptionally retentive memory, he was marked out from the first as a unique figure. Equally striking with his quickness and brilliancy, which won universal admiration, were the lively sense of humor and love of fun and practical waggery which some of his classmates now recall as his most salient characteristic and which diverted him in part from the sober

* Wheeler, History of Stonington.

† Proc American Antiq. Soc., new ser., Vol. 12, 1897–1898, pp. 16–22.

routine of the place His brain already outgrew his strength, and in the earlier part of the Junior year he was obliged to withdraw from college

For some time it seemed most improbable that he could ever resume study, but his own strength of will and his father's watchful devotion finally triumphed in his recovery.

While thus debarred from the continuation of his collegiate studies, his active mind found employment in natural history studies, in which he became greatly interested. His residence in Stonington was favorable for these pursuits, as it was the port for many vessels sailing to various parts of the world, whose captains brought home rare and curious objects, and he was thus enabled to add to his collections of specimens, particularly of shells, in which he took a special interest. His collection of these, thus gradually increased, as well as by his own researches along the shores of the region, eventually became one of the most complete in the country, and brought him an extensive correspondence, by which his name was becoming widely known as that of an authority upon the subject.

Among those with whom he was in frequent communication was Rev. James H. Linsley, of Milford, Conn., who, compelled by failing health to retire from the ministry, had devoted himself to the study of natural history, acquiring an extended knowledge of the fauna of Connecticut. Mr. Linsley was a member of the Yale Natural History Society, which had been formed not long before Trumbull entered college, and read several papers before it embodying the results of his investigations.

At the time of Trumbull's entrance to college, Benjamin Silliman, Jr., was the secretary and treasurer of the society, and the relationship to him would naturally have brought them into familiar acquaintance. It seems very probable that Trumbull must have been present at some of the meetings of the society while in college and have had access to its collections and library. However this may have been, he became known to it, and was nominated a corresponding member in April, 1842. It is a significant fact that among the most valuable series in the library of the society was a set of Kiener's

Coquilles, of which the greater part was acquired during the year 1839, the remainder early in the following year. This had been obtained at an expense that appears very considerable, having in view the limited resources of the society. Very probably we may here discover an important influence in determining his taste for the study of conchology, which for a time had such a predominant attraction for him, and which he pursued so successfully. Mr. Linsley had been a member of the society since 1837, and, in April, 1842, he read before it a paper which was a catalogue of the Mammalia of Connecticut. This was published in the American Journal of Science the same year, and was followed by similar catalogues of the birds, 1843; the fishes, 1844; the reptiles, 1844, and of the shells. The latter was published in 1845, after the death of Mr. Linsley, which occurred in December of the preceding year. The catalogues were copiously annotated, with curious and interesting observations, many of the notes having been furnished by Trumbull, with whom the author was in constant correspondence. The catalogue of the shells was especially enriched by his contributions, nearly one-third of the entries being attributed to him, and among them two new species which were named for him by Mr. Linsley.

Although thus apparently entered upon a career in which he gave promise of attaining prominence and distinction, he was destined to find congenial occupation in a widely different field. In 1847 he removed to Hartford, and entered the office of the secretary of state, where he remained as assistant to the secretary until 1852 Here his taste for historical studies, the result of his inheritance and home training, naturally led him to investigate the early history of the State and to utilize the original documents to which he had access. He soon formed the plan of reproducing the more important and interesting of these in a permanent form in print, and in 1850 he edited and published at his own expense the first volume of the Public Records of the Colony of Connecticut, prior to 1665, the full title of which is given in the list of his publications. This was followed, two years later, by a second volume, covering the period from 1665 to 1678, and, in 1859, by a third, which brought the series down to the year 1689, with an appendix of

documents illustrating the administration of Sir Edmund Andros. The contents of these volumes were not mere transcripts, but were accompanied with luminous notes which showed remarkable knowledge of the personalities and the social conditions of the period They are not only explanatory, but are important for the light they throw upon the documents themselves and the circumstances under which they came into existence. They form a contribution of permanent value to the early history of the State, the importance of which is attested by the frequency with which they have been utilized by subsequent writers as a source of information. The series thus so successfully begun was continued under the editorship of Dr. Charles J. Hoadley, and numbers many volumes.

Mr. Trumbull had been appointed State librarian and registrar in 1854, the first to occupy this position, and was a member of the committee to compile the statute laws of the State. He had been nominated for secretary of state in 1852, but failed of election. In 1853 and 1854 the nomination was offered to him, but declined, and in 1858 he was again appointed assistant to the secretary of state, which position he held until 1861. In this year he was elected secretary of state, and, being annually re-elected, continued in this office for five years.

In 1850 he had received from Yale the degree of master of arts, and was enrolled with his own class of 1842, and in 1871 the college conferred upon him the honorary degree of doctor of laws. He received the same degree from Harvard in 1887, and the degree of doctor of letters (L. H. D.) from Columbia in the same year. In 1873 he was appointed lecturer on the Indian languages of North America in Yale College, and his name appears thus in the list of instructors in the college catalogue until 1883, the appointment being virtually a complimentary one, as no duties were required of him in connection with it.

In April, 1855, Mr. Trumbull was married to Sarah A. Robinson, of Hartford, a sister of Hon. Henry C. Robinson, who was also connected with him by another bond of relationship, having married his cousin, Eliza Niles Trumbull. The year after his marriage was spent in a visit to Europe, Egypt, and the East.

Mr. Trumbull was a life member of the Connecticut Historical Society, having been elected to membership in 1847. He was its corresponding secretary from 1848 to 1863, and president from 1863 to 1889. Among the enterprises of the society was the publication of important papers connected with the early history of the State, in a series of volumes entitled "Collections of the Connecticut Historical Society." The first and second volumes of the series were edited by Trumbull, and were published in 1860 and 1870, respectively. To the second of these he contributed an elaborate article on the composition of Indian geographical names, and in the third volume, issued in 1895, under the editorship of Dr. Hoadley, was reprinted the Rev. Abraham Pierson's tract, "Some Helps for the Indians," with an introduction and notes by Trumbull. This had previously been published by him in a separate edition in 1873. It had been originally prepared for the Collections, but the edition of the third volume, when nearly ready for publication, having been destroyed by fire, its issue in that series was consequently delayed.

By a codicil to the will of Mr. David Watkinson, a generous and philanthropic citizen of Hartford, who died in 1857, a liberal bequest was made "for the purpose of establishing in connection with the Connecticut Historical Society a Library of Reference, to be accessible at all reasonable hours and times to all citizens and other residents and visitors in the State of Connecticut," and in a later codicil provision was further made for "the purchase of books for a Library of Reference (and not of circulation), to be kept in the rooms of, or in convenient connection with, the Connecticut Historical Society for consultation, but not to be removed therefrom." By the terms of the will the president of the society became *ex officio* a member of the board of trustees, but Dr. Trumbull had been named as a member of the board before he became president, and he was appointed librarian in 1863. He had been active in its foundation and in shaping its policy, and upon him fell the responsibility for the selection and purchase of its books. He prepared the first catalogue and discharged the duties of librarian until 1891, when on account of failing health he offered his resignation, which was accepted, but he was made librarian

emeritus, an honorary position which he held during the remainder of his life His labors for the library, inspired by his learning and enthusiasm, had resulted in making its collection of books one of the most valuable and important of its kind.

In 1864 he became an officer of the Wadsworth Athenæum of Hartford. In 1866 he edited a reprint of Roger Williams's "Key into the Language of America," with introduction and many notes, and in 1867 published an edition of Thomas Lechford's "Plain Dealing: or Newes from New England," with an introduction and very voluminous annotations. His work on early manuscripts had given him great skill in deciphering difficult handwriting, and he had become an expert, and had found recreation, in the study and interpretation of cipher writing. He had translated a large part of the shorthand of Lechford's manuscript Note-Book, for a projected edition, and had made many notes for it, which were incorporated in the edition which was published in 1885 by E. E. Hale, Jr He also translated portions of the diary of Henry Wolcott, which had been kept in shorthand, and published some selections from it. A volume published in 1876, in which he showed up the false Blue-Laws invented by the Rev. Samuel Peters and exposed the "unadulterated mendacity" of their author, resulted in some attacks upon his conclusions which were rather acrimonious, without, however, affecting their validity, and his critics were met with caustic refutation and complete discomfiture.

Dr. Trumbull was the editor of the Memorial History of Hartford County, published in two bulky quarto volumes in 1886. Although, in the preface, he did not claim for himself any great part in its preparation, the amount of labor he bestowed upon it was very considerable. The statement of the publisher, in a preface to the first volume, is to the effect that he

> has read, annotated, and corrected every page of the great work except the article in Vol. I * * * on the Original Proprietors, which is made up largely from his own notes and memoranda. And it should be added here that Dr. Trumbull's many and very valuable notes upon the early history of Hartford have been put by him at the disposal of the various contributors.

A glance through the volumes shows that this statement is not exaggerated, and that many of the writers of the different chapters had drawn upon his stores of information. He also himself contributed a chapter upon the Indians of the Connecticut Valley containing much that was new and of interest.

His work in the early history of New England had necessarily involved consideration of the aboriginal inhabitants, their language and history. From an early period he had made a study of their language, and had gradually been acquiring a knowledge of its vocabulary and grammatical structure that enabled him to undertake with confidence, and with the authority of a master, the editions of the works already mentioned, in which the language had been preserved. This was a task requiring unwearied patience, skill, and sagacity, for as the early records had not been made under the shaping influence of scientific philological principles, and were dependent upon a crude and unsystematic phonetic method, the attempt to find anything like a well-developed structure of grammatical forms and syntax would have seemed almost hopeless. But his persistent labors were abundantly fruitful of important results. Among other things they brought into clearer light the surprising fact that these languages possessed a grammatical structure of remarkable completeness, comparable with that of the Latin or Greek in wealth of structural forms, and excelling them in the power to express minute differences of meaning. Again, his study of the languages of different Indian tribes, as shown in his "Notes on forty versions of the Lord's Prayer in Algonkin languages," showed they had much in common and were to be regarded, not as independent tongues, but rather as dialectic variations from one parent stock.

In pursuing these investigations he had necessarily made a minute and prolonged study of Eliot's Indian Bible, which was the great treasure-house for the vocabulary of the Algonkin tongue, though popularly regarded as a sealed mystery, a monument of a vanished race, as well as of wasted energy and industry. His labors proved how erroneous were such views, and when his versions of the Lord's Prayer were brought to the notice of members of distant Indian tribes, though at first

they were not understood, when at length a familiar word was recognized the dialectic difficulties vanished, and the whole became intelligible. On this point the testimony of Rev. Edward Everett Hale, who was greatly interested in the Indian languages and in Eliot's work, is very pertinent:*

There was a fashion perhaps, among ignorant people, of saying that his great translation of the Bible was a book of no use to mankind. But everybody who knew anything about it, was obliged to say that in his study of the tongue of our poor Natick Indians he had unlocked the secrets of that extraordinary system of grammar which extends from the Arctic Ocean to Cape Horn. * * * The Algonquian language ranged so far to the southward that, as the society will remember, our associate Judge Forbes reminded us that Manteo, one of Raleigh's Indians from Roanoke Island, could have talked with Capt. Smith's Powhatan and Edward Winslow's Massasoit, and probably did

And again: †

When, therefore, it is carelessly said sometimes that Eliot's Bible is a wretched monument of waste of uniting industry and learning, the remark simply implies that the speaker does not know what he is talking about. Eliot's Bible is the most important book in the literature of a great race, now almost extinct, and, if you please to think so, to be extinct in another century But it is a perfect example of a system of grammar which proves to be more complete in detail than any of the grammars of any language known in Europe Its study indeed involves considerations in philological science, the value of which is not yet comprehended. As a vehicle only for the study of language, therefore, Eliot's Bible is a central book of the first importance.

Eliot accomplished wonders in his study of the Indian tongue, and of him, more truly than of any one else up to his time, could it be said that he had "unlocked the secrets" of its complex structure. Of the efforts of the early translators, Trumbull says: ‡

The greater number were first essays at translation into languages which the translators did not yet well understand. That they did not always succeed in giving the precise meaning at which they aimed, or that the rules of Indian grammar were often violated, is not to be wondered at. On the contrary, it is surprising, the difficulties of the task considered, that so much has, on the whole, been so well done.

* Proc. American Antiq. Soc, new ser. Vol 16, 1903, p. 178.

† Idem, p. 311.

‡ Trans. American Philol. Assoc., Vol. 3, 1872, p. 117.

Absolute mastery of an Indian tongue is, for one to whom it is not vernacular, the work of a lifetime. "Neither have I yet fully beat it out," John Eliot confessed, after twenty-five years' study of the mystery of Algonkin verbs

But the progress of investigation has only served to make more evident the immense difficulties which the student of these languages must encounter in his attempts to unravel their complexities and comprehend their subtle refinements in the expression of ideas. The very number of the grammatical forms systematically employed, and the almost unlimited variety in the shades of meaning conveyed by the mode of forming compound words, have perplexed many a student, or have led him into erroneous methods of interpretation. In his article on "The Algonkin verb," Mr. Trumbull remarks that "Professor H. Steinthal, in his psychological classification, regards the American languages as 'formless,'" and that "Professor Fr. Müller, in his memoir on the grammatical structure of the Algonkin languages (1867), and more recently in his Allgemeine Ethnographie (1873), concedes true verb-forms to the Mexican and Dakota languages, but denies them to the Algonkin and Iroquois." His own minute and prolonged analysis had led him to a different conclusion from that reached by these distinguished scholars, and he presented in elaborate detail the evidence in support of it. With characteristic modesty and caution he says, before giving the summary of his results:

The facts of language are seemingly opposed to the conclusion at which Professors Steinthal and Fr Müller have arrived *a priori* *Seemingly* opposed, I say, because I am not unmindful of Professor Steinthal's warning—that "some languages know how to supply the want of true form by devices so artful as *completely to attain the appearance* of real grammatical forms."

It is a part of Trumbull's great merit that he was able to establish the reality and definite purpose of some of these forms, and by long, patient, and persistent study was able to show their true place in the grammatical system. Another result of his labors was to emphasize the possibilities afforded by the American languages of discovering in their linguistic peculiarities interesting evidence relating to the early history and migrations of the aboriginal races.

As an aid to his work upon the Indian languages, Mr. Trumbull had formed a vocabulary of Indian words, and for many years was gradually improving and perfecting it. The character of this work is best described in his own words in a memorandum in the latest manuscript:*

In this first essay or rough draft of a dictionary of the Massachusetts language *as it was written by Eliot,* I followed Cotton in entering the verbs under the form that Eliot regarded as their infinitive mood. I discovered my error when it was too late to amend it in this draft. Ten years later I began a revision of my work, entering the verbs under the third person singular of their indicative present (aorist) in their primary or simple forms That revised copy I have been obliged to leave, at present, incomplete The materials for supplying its deficiency may be gathered from this volume.

The work as he left it comprised four manuscript volumes—one an English-Natick vocabulary, two others the first draft mentioned in his note, the fourth being the revised edition of the same, completed with the exception of a few letters, as above described. They had been written with his own hand in the beautifully clear and legible script so characteristic of his careful methods of work. The manuscripts, in accordance with his wishes, were after his death deposited by Mrs. Trumbull with the American Antiquarian Society, through whose agency the revised dictionary was published by the Government, in connection with the Bureau of Ethnology, under the supervision of Dr. Albert S. Gatschet, who was himself an accomplished scholar of the Algonkin tongue.

Great as were the services of Mr. Trumbull in the fields of historical and linguistic study already considered, his work as a bibliographer was perhaps even more conspicuous. His familiarity, even to minute details, with the life in the early New England communities was something marvelous. Hon. George F. Hoar, when president of the American Antiquarian Society, said of him:† He "knows the history, the life, the manners, even the gossip, of every New England generation from the beginning, as if he had been a contemporary."

Not less complete than his acquaintance with the moving

* Proc. American Antiq. Soc., new ser., Vol. 12, 1898, p. 320.

† Proc. American Antiq. Soc., new ser., Vol. 5, 1887–1888, p. 3.

spirits of that early time was his knowledge of their printed works, which was, indeed, unrivaled He was thus equipped, as few or none others have ever been, to render unerring judgment upon the significance and value of the early imprints He was able, almost by instinct, to find in some date, some chance expression or peculiarity of style, the clue to the authorship of an anonymous writing or the solution of some historical puzzle. A characteristic example of this is afforded in his article, "First essays at banking in New England." The information contained in it was derived from three anonymous pamphlets, the authors of which he was enabled to identify: One, Rev. John Woodbridge, by allusions to his personal history; a second, Cotton Mather, from the analogy of the contents of the pamphlet with certain passages in the Magnalia, as well as by characteristic peculiarities of style; the third, Rev. John Wise, from references of contemporary writers, and from the mention by them of incidents in his career which were readily verified.

In his fellow-citizen, Mr. George Brinley, Dr. Trumbull had for many years found a warm friend and one in full sympathy with his pursuits. If at times their desire for the acquisition of some rarity brought them into the position of competitors, this in no wise interfered with their friendship On the contrary, Trumbull ably seconded Mr. Brinley in the labor of many years which resulted in the formation of his rich and valuable collection of rare Americana. On the death of Mr. Brinley, in accordance with the terms of his will, the sale of the library was ordered, and Mr. Trumbull was made one of his executors He prepared the catalogue of the library, a monumental work in five volumes, published in the years from 1878 to 1893, and embracing 9,501 titles. The amount of information which it contains in regard to the various entries gives it a high value as a permanent contribution to bibliography, and makes it an indispensable aid to those interested in the history of early American printed works. It became so necessary a part of the working apparatus of the library that it was much sought for, and copies of it commanded a high price.

Among other works of similar character should be men-

tioned the list of books and tracts in the Indian language, or designed for Indians, published in 1873 as a part of an article on the "Origin and early progress of Indian missions in New England," and the important volume, published in 1904, embodying the labors of many years in forming a list of books published in Connecticut before 1800. The nature of this work is indicated in the following statement from the Introduction, p. vii:

> Among the many literary and bibliographical treasures left by the late James Hammond Trumbull is a series of manuscript slips to which he had prefixed the title, "List of Books Printed in Connecticut, 1709-1800" Some of these slips bear evidence of having been written more than forty years ago, from which time their number has been added to down to the time of Dr Trumbull's death in 1897, although during his later years the additions were few, most of the work having probably been done before 1878. Each title is in the delicate and beautiful handwriting of Dr Trumbull, and each is written with the care and neatness so characteristic of his work.
>
> By the courtesy of Miss Annie Eliot Trumbull this list, prepared by her father, has been placed at the disposal of the Acorn Club for printing, and Miss Trumbull has still further increased the club's indebtedness to her by comparing the slips with other manuscript notes left by her father, a comparison which resulted in a few corrections and in the addition of a number of titles that had been noted but not previously incorporated in the list.

The work was edited by Miss Trumbull, who also prepared the lists at the end and the index.

These works by no means complete the tale of his bibliographical work. Hardly less important must be reckoned the vast amount of valuable material embodied in the notes with which he enriched the many works edited or published by him, and the aid he so generously gave to many workers by his correspondence, involving often much labor and research.

Mr. Trumbull's activities were not limited to the works hitherto enumerated. He was a member of many societies, and his communications were frequent and of great value. His connection with the Connecticut Historical Society has already been mentioned. In 1855 he was elected a member of the American Antiquarian Society. He furthered the efforts of the society to collect the public documents of the States by forwarding ten volumes of Connecticut documents, dating from

1851 to 1854, and thereafter made many donations to it He was appointed in 1870 a member of the committee to report on papers relating to Indian remains and graphic symbols, and made a report of which a brief notice is given in the proceedings of the society. He was made a member of the council in 1872 and secretary of foreign correspondence in 1874 These positions he continued to fill until the close of his life, thus serving twenty-five years in the former and twenty-three years in the latter. He was a frequent attendant of its meetings and an active participant in its proceedings. Some of his most valuable contributions to American history were contained in the reports of the council prepared by him, or in papers read before the society.

He was a member of the American Oriental Society from 1862, and read several papers before it. Of the American Philological Association he was one of the founders. He was present at the first meeting of the association, held at Poughkeepsie, in July, 1869, when he was made a member of the committee to nominate permanent officers, also a member of a business committee, and was elected treasurer of the association. In 1873 he was made vice-president and in 1874 elected president of the association for the following year. He was a member of the executive committee from 1875 until 1883; also, in 1875, of the committee on the reform of English spelling. The annual address of the president, in 1875, was given by him, treating of some general characteristics of Indian languages and upon spelling reform. His papers read before the association were very numerous. They were largely devoted to linguistic questions relating to the languages of the American Indians, but some were of more general philological interest. Most of these were afterwards published in the volumes of the proceedings and transactions, a few, more or less modified or extended, elsewhere.

Dr. Trumbull was elected a member of the National Academy of Sciences in 1872. He often attended the meetings of the academy, where his presence was most welcome, and although he did not present any papers before it, his wit and brilliant conversational powers did much to enliven and brighten the social intercourse among the members. He had been ap-

pointed in 1882 to prepare for the academy the biographical memoir of Hon. George P. Marsh, deceased not long before, but the decline of his health did not permit him to accomplish the work, and in the later years of his life he was no longer able to be present at the meetings.

The societies already mentioned are those with which Dr. Trumbull was most closely identified, but his prominence had brought him membership in many others. He was a corresponding member of the Massachusetts Historical Society from 1850; also member of the historical societies of Maine, Rhode Island, New York, and Wisconsin, and of the American Ethnological Society. He was from a very early date a member of the American Association for the Advancement of Science, and was associate fellow of the American Academy of Arts and Sciences, Boston. He was one of the founders of the Monday Evening Club of Hartford, and retained his association with it as long as he lived.

Although he was so fully absorbed in other interests, Dr. Trumbull had not lost the taste for scientific pursuits which had been so active in his early life. The knowledge he had gained in Stonington was made available later when he aided Prof. S. F. Baird in his work in reference to the history of the whale and seal fisheries on the northwest coast of America. He aided Dr. Asa Gray in the preparation of a paper upon the characteristics of North American Flora for the meeting of the British Association at Montreal in 1884, and he had previously co-operated with him in 1877 in the production of an article in the American Journal of Science on the history of the so-called Jerusalem artichoke, the greater part of which, filled with curious historical learning, was contributed by him, with an introductory note by Gray; and again, in 1883, the two were associated in the pages of the same journal in a long and elaborate review of De Candolle's "Origin of Cultivated Plants," which appeared in three parts, running through several numbers of the journal.

The following, from a notice which appeared in the Hartford Courant of August 6, 1897, gives an insight into his atti-

tude toward historical writing and the high estimation in which he was held by those who knew him well:

Dr. Trumbull might have given us a history of Connecticut that would have stood first among American histories. He was often urged to do so, but he would never undertake the work; and his friends, some of them certainly, attributed this shrinking from something so much to his taste to his fear that it might contain some statement that some other authority would controvert, perhaps disprove. The same caution spread throughout all literature would result in the abolition of histories; but Dr. Trumbull was not going to commit himself to the possibility of blundering, and so never wrote the history that would have been for himself a worthy monument, and for the rest of us a perpetual source of pride and satisfaction. It is a curious freak of fate that the very trait which made what he did write so valuable prevented this crowning work.

Dr. Trumbull was consulted by a multitude of people, and not always with the most satisfactory results. Those who thought he had nothing to do but answer letters sometimes found he had not time for that People who questioned him foolishly or in annoying ways sometimes got curt replies. Among such he was very likely reckoned somewhat crusty. But he was exceedingly helpful to those whom he saw to be in earnest, and was full of live sympathy with those whose inquiries impressed him as leading to right results. With such he would spend much time, show them authorities, and freely contribute the great assistance that his large abilities made possible.

Dr. Trumbull did not, it is true, complete any works of great extent, and the multiplicity and exacting nature of his occupations would be a sufficient reason for that, apart from the hesitation due to his critical fastidiousness. But although much of his writing was upon detached topics, which gave it, in appearance, something of a fragmentary character, the amount he accomplished was very great, and from its substantial character it will have a permanent value. If his writings upon the Indian languages were to be collected they would form a large volume and constitute probably the most important single contribution to this difficult subject.

During the later years of his life Dr. Trumbull rarely left Hartford, and his activities were greatly lessened by his declining health and failing strength. He continued to grow gradually weaker physically, though hardly consciously to himself, and apparently suffering little or no abatement of his

mental powers. In the summer of 1897 he suffered an attack of grip, and from that failed rapidly. After a period of unconsciousness he passed away on the fifth day of August, 1897, in the seventy-sixth year of his age. He was survived by Mrs. Trumbull and an only daughter, Annie Eliot Trumbull, who had been his devoted assistant, and herself a well-known and successful writer.

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The following list contains the titles or subjects of the principal published writings of Dr. Trumbull, and of works issued under his editorial supervision. It does not include his numerous contributions to newspapers, except in some instances where these have been reproduced in a more permanent form, or have from their subjects special interest; nor, in general, the innumerable notes embodied in the works edited by him. For convenience the titles are arranged in several groups according to their subjects.

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The Public Records of the Colony of Connecticut, May, 1678–June, 1689; with notes and an appendix comprising such documents from the State archives, and other sources, as illustrate the history of the colony during the administration of Sir Edmund Andros; Transcribed and edited, in accordance with a resolution of the general assembly. Vol. 3, Hartford, 1859, pp. XIII, 538.

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> This Catechism is the only book printed in any Indian dialect of "these southern parts." It is believed to be the first work of an author belonging to either of the two colonies (Conn. and N. H.) that was printed in this country. It supplies linguistic material of some value to philologists, the Quiripi dialect having a place between the dialects of Massachusetts, Narragansett, and eastern Connecticut, and those of the Middle States.

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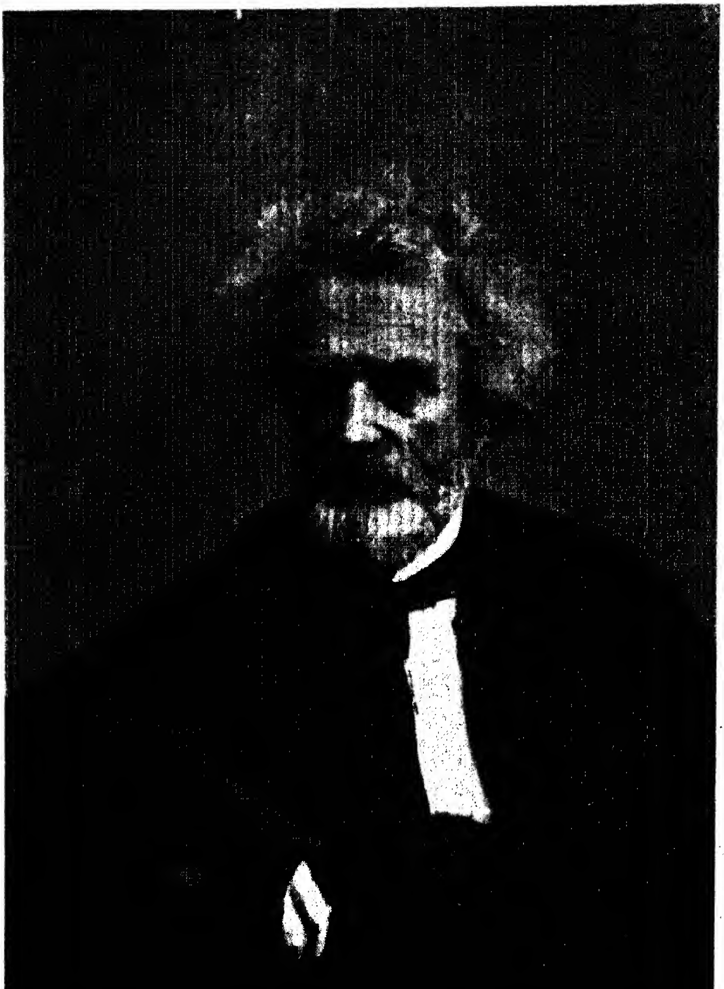

W. H. C. Bartlett
Profr. Nat. & Expt. Phy.

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
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BIOGRAPHICAL MEMOIR

OF

WILLIAM H. C. BARTLETT

1804-1893

BY

EDWARD S. HOLDEN

PRESENTED TO THE ACADEMY AT THE APRIL MEETING, 1911

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Of the biographical memoirs which are to be included in Volume VII, the following have been issued

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WILLIAM H. C. BARTLETT.

William H. C. Bartlett was born in Pennsylvania in September, 1804. He died at Yonkers, New York, on February 11, 1893, aet. 89. His parents moved from Pennsylvania to Missouri, and settled there while he was yet an infant. His early education is said to have been meagre, but his natural abilities attracted the attention of his fellow-townsmen, and in 1822, at the age of 17 years, he was appointed a cadet at West Point. It is said that his appointment was at least partly due to the friendly offices of Senator Thomas H. Benton.

From 1822 onwards his career is well recorded. The following is summarized from General Cullum's Biographical Register of the Officers and Cadets of the U. S. Military Academy, with a few additions.

William H. C. Bartlett; Class of 1826; born in Pennsylvania, 1804; appointed from Missouri, 1822; graduated No. 1 in a class of 41 members Among his classmates were General Thomas Jefferson Cram; General Albert Sidney Johnston (C. S. A.); General Samuel P. Heintzelman; General Augustus J. Pleasanton; General Amos B. Eaton; and General Silas Casey. He was in the corps of cadets at the same time with the classes of 1823, 1824, 1825, 1826, 1827, 1828, and 1829, and was thus associated with the following named officers, among many others: Major Alfred Mordecai, General George S. Greene; General Lorenzo Thomas; General Hannibal Day; General E. B. Alexander (C. S. A.); Professor Dennis H. Mahan; Robert P. Parrott; Alexander Dallas Bache; General Daniel S. Donelson (C. S. A); General Benjamin Huger (C. S. A.); General Robert Anderson; General Charles F. Smith; General William Maynadier; Bishop and General Leonidas Polk (C. S. A.); General Gabriel J. Rains (C. S. A.); General Philip St. G. Cooke; Professor Albert E. Church; Professor W W. Mather; President Jefferson Davis (C. S. A); Charles Mason; General Hugh W. Mercer (C. S. A.); General T. F. Drayton (C. S. A); General Robert E. Lee (C. S. A.); General James Barnes; Professor Charles W. Hackley; William R. McKee; General Joseph E. Johnston (C. S. A.); General Albert G. Blanchard (C. S. A.); Professor and General Ormsby McK. Mitchel; General Sidney Burbank; General William Hoffman; General Seth Eastman; General Thomas Swords; Professor James Clark, S. J.; General Benjamin W. Brice; and General Theophilus H. Holmes (C. S. A.).

Among these selected names there are three corporators of the National Academy of Sciences: Bartlett, Bache, and Mahan The names of distinguished military commanders in the war with Mexico and in the Civil War will be familiar. Bishops, ministers of the gospel, priests, presidents and professors of colleges, and judges are there enumerated. Some of the pillars of our Coast and Geodetic Survey are named, with others who surveyed the boundary lines of our country To those who are familiar with the early history of railways in America some of these distinguished names will recall the builders, engineers, managers, directors, and presidents of our first railway lines.

I am tempted to set down in order the names belonging to this latter group because the memory of the great services of graduates of the Military Academy in this respect is growing faint, and because this should not be so. Among the cadets of the years 1823–29, who were at West Point with Bartlett, the following were closely connected with the beginnings and with the development of our railway system or with water works and canals Only those who served in civil capacities are named, none who were in the active army, and none except those of the seven classes of 1823–29:

G. S. Greene, canals, Croton water works, G W Long, chief engineer of the Alton Railroad, Illinois, etc.; J. M. Fessenden, chief engineer of the Boston and Worcester Railroad, etc.; R. E. Hazzard, engineer of the Baltimore and Ohio Railroad; J N Dillahunty, engineer of the Baltimore and Ohio Railroad, W. B. Thompson, chief engineer of the Goldsboro Railroad, etc.; T. S. Brown, chief engineer of the Erie Railroad, etc., consulting engineer to the St Petersburg and Moscow Railroad, etc.; A. H. Brisbane, chief engineer of various railroads in Georgia; E B. White, engineer of railroads in South Carolina and North Carolina; John Childe, engineer of the Baltimore and Ohio, Mobile and Ohio, and many other railroads; A J. Center, superintendent of the Panama Railroad, etc.; R. C. Tilghman, harbor improvements on Lake Erie, etc.; Edmund French, engineer of the Croton dam, Hudson River Railroad, etc., Charles Mason, president of the Burlington and Northwestern Railroad Company, etc.; James Barnes, chief engineer of the Seaboard and Roanoke Railroad, etc.; W. R. McKee, engineer of the Charleston and Louisville Railroad, etc.; O. McK. Mitchel, chief engineer of the Ohio and Mississippi Railroad, etc.; T. A Davies, engineer on Croton aqueduct, etc.; A. G. Blanchard, chief of survey of the New Orleans and Opelousas Railroad, etc.; A. Snyder, engineer of the Reading Railroad, etc

These twenty ex-officers, graduated between the years 1823 and 1829, held the chief positions in the railways of the United States. Together with many others, not here named, they made the preliminary surveys of the early American railways, located them, built them, and managed them. The first railways of Cuba, Mexico, South America, and Russia were their work.

Cullum's Biographical Register shows that no less than 49 graduates between 1802 and 1902 have been *chief* engineers of railways, and 22 have been presidents of railroad companies In the period of 1802–1900 no less than $383,000,000 have been expended by engineer officers (all graduates) on the improvement of rivers and harbors; from the time of Bonneville (U. S. Military Academy, 1815) they have been pre-eminent as explorers, surveyors of boundaries, of the routes for the Pacific railways; the Coast Survey was founded by a professor from West Point, and brought to its highest efficiency under Bache, a graduate of 1825; the Lake Survey was created by Comstock (U. S Military Academy, 1855); the 40th Parallel Survey (King) and the Surveys West of the 100th Meridian (Wheeler) were executed under the direction of the engineer department; the lighthouses of the United States have all been constructed by graduates, no less than 16 graduates have been members of the National Academy of Sciences

To resume the official record of Bartlett, after this digression: He was graduated and promoted in the army to be second lieutenant in the Corps of Engineers July 1, 1826, and served in this capacity to April 20, 1836, on which date he was appointed to be professor of natural and experimental philosophy in the Military Academy, in succession to Prof. Edward H. Courtenay. On February 14, 1871, he was retired from active service, on his own application, "after (more than) forty years of continuous service."

He served at the U. S. Military Academy as assistant professor of engineering from August 30, 1826, to April 21, 1827, and as principal assistant professor in the same department to August 30, 1829; as assistant engineer in the construction of Fort Monroe, Virginia, in 1828; and of Fort Adams, Newport, Rhode Island, 1829-32; as assistant to the chief engineer at Washington, D. C., 1832-34; and as acting professor of natural and experimental philosophy at the Military Academy from November 22, 1834, to the date of his appointment as full professor, April 20, 1836.

He received the degree of A. M. from the College of New Jersey (Princeton) in 1837; and of LL. D. from Hobart College (Geneva, N. Y.) in 1847. He was a member of the American Academy of Arts and Sciences (Boston) and of the American Philosophical Society (Philadelphia), and one of the corporators and original members of the National Academy of Sciences in 1863.

Bartlett's work at Fort Adams was under the immediate direction of Colonel J. G. Totten. Difficulties that arose in the laying of the coping of the stone walls of this fortification led to an investigation of the expansive coefficients of various building stones in the years 1830 and 1831. The results are printed in the American Journal of Science, Vol. 22, 1832, pp 136–140 The methods employed seem to be simple and direct and the results of sufficient exactness.

It was during his service at Fort Adams that Bartlett married (February 4, 1829) Miss Harriet Whithorne, daughter of Samuel Whithorne, a merchant of Newport. Eight children were born of the marriage, of whom three sons and two daughters were living with their mother at the time of his death, in 1893.*

In the year 1840 Professor Bartlett applied to Colonel J. G. Totten, Chief Engineer of the Army and Inspector of the U. S. Military Academy, for permission to go abroad to inspect the astronomical observatories and establishments of Europe. He was absent from West Point from July 1 to November 20, 1840, and his manuscript report of 52 pages (now in the library of the U. S. Military Academy) was submitted on February 16, 1841. He visited the observatories of Greenwich, Oxford, Cambridge, Dublin, Armagh, Edinburgh, Paris, Munich, and Brussels; and the workshops of Troughton and Simms, Dolland, Jones, Grubb, Gambey, Ertel, Merz, and others. His report is general in its nature, but details are given of devices and arrangements that seemed important.

This visit led to the equipment of the observatory of West Point, whose instruments were ordered on the recommendation of Bartlett, set up, and used by him and his assistants, notably by his son-in-law, afterwards Lieut. General John M. Schofield.

WEST POINT OBSERVATORY

1843–1871.

Professor Loomis' volume, The Recent Progress of Astronomy, Especially in the United States (New York, 1851), con-

* Scharf, J. T. History of Westchester County, New York, Vol. I, p. 622.

tains an excellent description of the observatory of the U. S. Military Academy. The first equatorial had an objective, by Lerebours, of six inches aperture. It was replaced in 1856 by a 9¾-inch objective by Fitz. A transit instrument by Ertel (5¼ inches aperture), with a Hardy sidereal clock, occupied the east tower. A mural circle by Simms (5 feet in diameter, with a telescope of 4 inches aperture) occupied the west tower. Professor Loomis remarks (p. 170): Professor Bartlett "has made a good many observations with the meridional instruments which have not yet (1851) been published. He is at present engaged in a regular series of observations on the stars enumerated in the notes to the British Association catalogue, and also on the planet Neptune."

The manuscript records of these observations I saw in 1872–73, and formed the project of reducing and publishing them in honor of my old teacher, and of my Alma Mater, especially as my examination showed the work to be of high quality. I regret that the leisure to carry out my youthful project has never come in the course of a long and busy life.

In the reconstruction of the building and the removal of the observatory to a new site (1879–1883, or later) the manuscripts were lost, and have not yet been found. For that reason no further reference can be made to them here, except to give my personal recollection, based on computation, that the precision of Bartlett's work with the mural was of the same order as that of that prince of observers, Professor J. H. C. Coffin, whose work I was then studying.

OBSERVATIONS AND ORBIT OF THE COMET OF 1843.

In March, 1843, the equatorial telescope (objective of 6 inches by Lerebours; mounting by Grubb) was the only instrument fully mounted at West Point. It was utilized by Bartlett to observe the Comet of 1843 on four nights of March and April (the weather being unfavorable on other nights).

In a communication read to the American Philosophical Society,* Bartlett gives the reduction of his observations as well as the elements of the comet derived from places obtained

*Proc. American Philos. Soc., Vol. 3, p. 151.

on March 25, March 29, and April 2, together with the results of measures of the diameter of the nebulous envelope of the head. The original paper was accompanied by drawings and a description of the new observatory, then nearly completed.

COMAS AND TAILS OF COMETS

In 1859 Bartlett printed in the American Journal of Science, Vol. 29, pp. 62–64, a short paper on the comas and tails of comets It is very general in form and seeks to give mathematical expressions for the circumstances of the relative motion of the material elements of any aggregation of molecules—a comet, for instance—immersed in the ether of space and acted on by light-rays from the sun. He first shows how the forces from the sun and from the elements of the comet may produce light waves in the ether and render it *self-luminous*. And next it is shown how the internal motions of the material elements of the comet's head, influenced by the light-rays from the sun, may render the comet itself *self-luminous*.

He concludes that the comet's head can have no phases, and altogether denies the presence of cometary material in the coma and in the tail. These appendages are to be regarded, he says, as but phenomena due to the reciprocal action of the ethereal and cometary molecular forces. The coma and tail are, as it were, but parts of a luminous shadow and have no objective existence. Applying the same principles to the zodiacal light, he makes the deduction that the component molecular motions inside the sun are greater in the direction of the solar axis than in any other.

BARTLETT AS A PURE MATHEMATICIAN.

In this paper, as in another on polarization that will be cited, it appears to the writer that Bartlett looks on the phenomena he is discussing with the eyes of a pure mathematician, and this in spite of the fact that he expressly states the cometary problem to be not one of mathematics, but of physics. By physics it would seem that Bartlett meant mathematical molecular physics, and that he rested in his conclusions without the slightest temptation to test them by appeal to observa-

tion or to experiment. Both papers suggest that Bartlett was entirely satisfied as to the validity of his results so soon as he was sure that his analytic expressions were correctly deduced. The anxiety of a physicist about the data introduced, and respecting the comprehensiveness of his formulas, did not seem to affect him in any marked degree.*

Somewhere in Bartlett's book on Optics there is a conclusion like the following: *k* is small, and therefore we can hear, but cannot see, round a corner. This is the view of the pure mathematician. The enunciation should be: Since we can hear, and not see, round a corner, *k must* inevitably be small, as it turns out to be in the formula.

His paper, On the direction of molecular motions in plane polarized light (American Journ. Sci., Vol 30, 1860, pp. 361–366), seems to the writer to exhibit the same purely mathematical point of view, and to suggest that it may have been characteristic.

Bartlett first discusses the living force and the quantity of motion in a plane polarized wave, and next their resolution by deviating surfaces. By transformations which seem to the writer to be ingenious, he arrives at simple formulas which he interprets as demonstrating that the vibrations of the molecules in a plane polarized wave must be parallel to the plane.

The writer is not competent to detect the fallacy in this conclusion, but it is certain, according to Lord Kelvin, that this result is to be denied.†

ON THE SOLAR ECLIPSE OF 1854, MAY 26.

In the Astronomical Journal (No. 77, November 10, 1854) Bartlett had an important paper on the partial solar eclipse of 1854. He measured the distance between cusps during the eclipse with a double-image micrometer and noted the corresponding times. But his work is important for another reason. For the first time in America photography was util-

*The formula in the middle of page 64 should read: R. N. sin (etc.), and not as printed.

†Chwolson: Physique—l'énergie rayonnante; Chap. XV, page 729, where Kelvin's Baltimore lecture (No. XVIII) is cited.

ized for astronomical measurements. During the eclipse Mr. Victor Prevost, of New York, assisted Bartlett in obtaining photographs of the solar disk; the distances separating the cusps were subsequently measured on the glass negatives. The telescope employed was of six-inch aperture and the solar focal length was eight feet. A small camera was attached to the eye end; the plates must have been wet plates, and the exposures were practically instantaneous. The solar image was about 7/8 of an inch in diameter. Nineteen photographs were taken and accurately timed.

ASTRONOMICAL PHOTOGRAPHY.

The very first essay in astronomical photography was that of Prof. John Henry Draper, of New York, who in the year 1840 took a satisfactory daguerreotype of the moon. The experiments of Draper were repeated by George Bond at the Harvard College Observatory, in 1850, and a lunar daguerreotype made by him was exhibited in London at the Crystal Palace in 1851, where it attracted great attention. Solar daguerreotypes were first taken by Foucault and Fizeau in Paris, in 1845, on the advice of Arago. A small but excellent daguerreotype of the total solar eclipse of July 28, 1851, was taken by Busch at Königsberg. Up to this time photography had not been utilized in measurement, and Bartlett was, I think, the first to so employ it.

The first daguerreotype of a star was taken by George Bond in 1850, and the first photograph of a star in broad daylight was made by the writer at the Lick Observatory in 1889 to test a theory of photographic vision. The first photograph of a nebula was made by Dr. Henry Draper and M. Janssen in 1881. Sir David Gill first photographed a comet in 1882 The earliest photograph of a star-spectrum showing measurable lines was made by Henry Draper in 1872, though Huggins had obtained an *image* of the spectrum of Sirius as early as 1863. The first photographs of the inner corona were made by De la Rue in 1860.

All these data refer to ancient history, and the results obtained are insignificant compared to the magnificent negatives

of today. Still they have their place in the history of astronomy, and for Bartlett it may be claimed, I believe, that he was the first to obtain quantitative results from astronomical photography.

BARTLETT AS A TEACHER (1836–1871).

Professor Bartlett is best known to the general public by his series of text-books on Acoustics, Optics, Astronomy, Mechanics, and Molecular Physics.

They were used at many schools and colleges and gave him a definite standing among his fellows. Of the Astronomy I can say that, while it has distinct merits, it is not so directly useful for the purpose of training an army officer for practical work in the field as the contemporary text-books of Loomis. Still it must be remembered that this volume gave their only preliminary training in astronomy to a long line of engineer officers whose work on the Coast Survey, the Lake Survey, the Mississippi River Survey, and on many boundary surveys has been distinguished for accuracy and precision. The basis laid by the book and the teacher was sound.

Of the other text-books of Professor Bartlett, the Analytical Mechanics is the most important. Its first edition was dated in 1853; the ninth in 1874. Regarding it I will quote a paragraph by Bartlett himself, taken from his testimony before a commission appointed by Congress to inquire into the affairs of the U. S. Military Academy, Hon. Jefferson Davis, chairman,* and parts of a memoir of Bartlett written by his pupil and successor in the professorship at West Point, Colonel P. S. Michie.†

Professor Bartlett's own testimony is:

The text-books in natural and experimental philosophy have been prepared expressly for the cadets of the Military Academy. They have a threefold purpose—mental discipline, a corresponding knowledge of the subjects of which they treat, and a confirmation, in the minds of the students, of their previous mathematical course. The text on mechanics, the groundwork of the whole, begins with the simplest elements of physics. and such general facts in regard to the action of forces as are

* 36th Congress, 2d session, Senate Misc. Doc. No. 3, pp. 350.

†Annual of the Association of Graduates, U. S. Military Academy, for 1893.

furnished by experience, and which comprehend all special cases of nature. These are fully discussed, and a mathematical formula, an expression of the laws by which forces are connected with matter, is deduced. From this point the work is purely deductive, and presents to the student a connected discussion, instead of a series of detached propositions, as in most texts upon the same subject This formula is made a never-failing source whence may flow, through the channel of mathematical analysis, and in the natural order of sequence, all the laws of matter, and the rationale of all physical phenomena The method is natural, simple, and comprehensive, and it saves to the student a great deal of useless labor, by avoiding the necessity of new statements and demonstrations on the presentation of new cases and new data. It requires, to be sure, more labor from the student at the beginning; but that labor is rewarded by ample returns in the increasing ease with which he may progress, after mastering first principles, and in the facility with which the text may be reviewed

The totally new aspect given, within a few years, to that branch of natural philosophy embracing what were formerly called the 'imponderables,' viz, light, heat, and electricity, made it necessary, in my judgment, to add to the mechanics of solids and of fluids, that of molecules; and it is proposed to replace the present text-book on acoustics and optics by another, embracing, in addition, heat and electricity, which shall be purely deductive, and little else than corollary to this new branch of mechanics *

Professor Michie, Bartlett's successor, thus summarizes the text-books prepared by his predecessor and used by himself for many years:

Professor Bartlett, on assuming the duties of his department, continued the text-books and methods of his own predecessor, until he was able to make suitable modifications more advantageous to his pupils. Mechanics was taught from Courtenay's translation of Boucharlat until September, 1850, when it was replaced by Bartlett's Synthetical Mechanics. Some opposition having developed against this work, on the ground that it was of too elementary a character for students familiar with the calculus, he prepared his Analytical Mechanics to replace it, and the latter was adopted as a text-book August 29, 1853. His Treatise on Optics, the first of his text-books to be prepared, was introduced into the course February 16, 1839, and it continued to be used until it was superseded by his less difficult, but more comprehensive work, Acoustics and Optics, September 27, 1852. Bartlett's Spherical Astronomy, adopted by the academic board September

* Report of the Commission to Examine the Military Academy at West Point, 1860, pp. 110-111.

5, 1855, was the last of his series of scientific text-books. While all of these works were of a high grade, clearly and concisely written, and valuable contributions to the higher scientific education, his lasting fame will rest more solidly upon his Analytical Mechanics This work passed through nine editions and was used in many institutions of well established scientific reputation. He always expressed a just pride in the success he had attained in its preparation, and it exhibits in a marked degree the special tendency of his own talent for generalization. He distinctly perceived that all natural phenomena are nothing more than particular exhibitions of a great general law, but yet capable of being most simply expressed by a single formula His perception of this great truth is thus eloquently expressed in his preface:

"The design of the author is to give to the classes committed to his instruction, in the Military Academy, what has appeared to him a proper elementary basis for a systematic study of the laws of nature. The subject is the action of force upon bodies—the source of all physical phenomena—and of which the sole and sufficient foundation is the comprehensive fact, that all action is ever accompanied by an equal, contrary, and simultaneous reaction. Neither can have precedence of the other in point of time, and from this comes that character of permanence, in the midst of endless variety apparent in the order of nature. A mathematical formula which shall express the laws of this antagonism will contain the whole subject, and whatever of specialty may mark our perceptions of a particular instance will be found to have its origin in corresponding peculiarities of physical condition, distance, place and time, which are the elements of this formula. Its discussion constitutes the study of Mechanics. All phenomena in which bodies have a part are its legitimate subjects, and no form of matter under extraneous influences is exempt from its scrutiny. It embraces alike, in their reciprocal action, the gigantic and distant orbs of the celestial regions, and the proximate atoms of the ethereal atmosphere which pervades all space, and establishes an unbroken continuity upon which its Divine Architect and Author may impress the power of His will at a single point and be felt everywhere. Astronomy, terrestrial physics, and chemistry are but its specialties; it classifies all of human knowledge that relates to inert matter into groups of phenomena, of which the rationale is in a common principle; and in the hands of those gifted with the priceless boon of a copious mathematics it is a key to external nature"

Professor Bartlett's own preface to the ninth edition of his Analytical Mechanics may be quoted here to give his last word on a subject near to his heart:

Twenty years ago, the course of Mechanics taught, for several previous years, to classes in the United States Military Academy, was published in the first edition of this work.

In that edition the following assertion was made:

"All physical phenomena are but the necessary results of a perpetual conflict of equal and opposing forces, and the mathematical formula expressive of the laws of this conflict must involve the whole doctrine of mechanics. The study of mechanics should, therefore, be made to

consist simply in the discussion of this formula, and in it should be sought the explanation of all effects that arise from the action of forces."

From the single fundamental formula thus referred to, the whole of analytical mechanics was then deduced.

That formula was no other than the simple analytical expression of what is now generally called *the law of the conservation of energy,* which has since revolutionized physical science in nearly all its branches, and which at that time was little developed or accepted.

It is believed that this not only was the first, but that it even still is the only treatise on analytical mechanics in which all the phenomena are presented as mere consequences of that single law.

And in offering to the public this new edition, which has been most carefully revised and in many parts rewritten, one of the principal objects sought has been to render it more worthy of use, by making it what it ought to be in view of the great progress achieved during the last twenty-five years, in consequence chiefly of the more general recognition and acceptance of the grand law of work and energy, by Newton called that of action and reaction. (Yonkers, New York, 1874.)

I add a few reflections of my own upon the earlier book of Bartlett, namely: Elements of Natural Philosophy, I: Mechanics, by W. H. C. Bartlett, LL. D., 2d edition, New York, 1851, 1 vol., 8vo, pp. 632. The first edition of this book was published in 1850. The preface states that the book was written with constant reference to the works of Poncelet, and that much valuable assistance was derived from Peschel.

No detailed examination of the volume has been made by the present writer, but such examination as has been made seems to show that this text-book was very well suited, indeed, to the cadets of the academy. Its explanations and proofs are clear and not too brief. Each paragraph has a rubric in the margin summarizing its contents; diagrams are freely used, and numerical examples are worked throughout the text. The book has no collection of unworked problems so necessary for students, but problems were given out by the professor (if we may judge by his subsequent practice in this respect). The excellent fashion of presenting many unworked problems in a text-book had not then been set by the English text-books, written to prepare students for test examinations.

As I turn over the pages it appears to me somewhat regret-

table that this excellent volume was not made the basis of the course in mechanics at the U. S. Military Academy, supplemented, as required, by a higher treatise in which the subject was treated analytically for the use of the upper men in each class—the engineer, ordnance, and artillery officers of the future. I think it is the judgment of a very large number of graduates that their study of mechanics, and especially of molecular mechanics, from the text-books of Bartlett and similar treatises, has been less profitable and of less practical use in their military careers than it might have been. The ideal of the mathematical studies at the academy is to create *power* by means of *useful* knowledge. There is no science or art so practical as war, and all our training must be directed toward giving, *first,* power—mental and moral—and toward giving it, *second,* through useful, available, practical knowledge.

Perhaps the result of Bartlett's training upon the mass of his pupils might have been even more fruitful than it was if his first judgment had been followed, and if he had not been obliged to revise it to conform to the views of his colleagues. The revision itself was admirably done, and those who were ready to profit by his teaching profited exceedingly.

Perhaps this is an appropriate place to point out that the U. S. Military Academy is not, and never has been, a school of pure science. It is a technical school for war. Pure science is taught as a means of mental discipline, but still more as a basis for the application of science to the military art. This is the fact, and it ought always to be so. The conditions of the country were such in the years 1802 to 1860 that the scientific education at West Point was the best then attainable, particularly when one remembers that invaluable moral training which comes from discipline, a high sense of honor, and a simple unquestioning devotion to duty.

The atmosphere of the École Polytechnique is very different from that at West Point. There was no such stimulating criticism for the members of its academic board as surrounded their contemporaries in Paris. It is for this reason, I think, that Bartlett, and his colleagues as well, were not as keen to follow the progress of their sciences as they certainly would have been had they lived in an intellectual atmosphere like that

of Paris. They conscientiously prepared the texts from which cadets were taught, and laboriously and minutely corrected and improved them year by year. Their chief interests were in the teaching of their sciences, not in advancing them. This was as it should be. The object of the academy is to produce competent officers equipped for instant work, not primarily to add to science itself.

The alert and vigorous mind of Bartlett would, I think, have developed very differently under different conditions. Whenever his interest was excited his work was of a high order. Witness his investigation of the strains in rifled ordnance (Memoirs Nat. Acad. Sci., Vol. I) for his friend and neighbor, R. P. Parrott, and his photographs of the solar eclipse of 1854 (the first made in America), and his researches as actuary of the Mutual Life Insurance Company of New York. His daily life at West Point was filled with routine duties, all performed in the most conscientious and best manner. Lacking the stimulus of intellectual equals in his own pursuits, he led a life of easy usefulness, contented with achievements not fully commensurate with his great powers. Under different circumstances of stimulus, criticism, and approval he would have become a still more shining light among his fellows. The Military Academy gained where science lost.

From my own recollections I can say that he was an accomplished teacher—luminous, exact, suggestive, inspiring—more particularly for the upper sections of the class; apt to become nervous and impatient with slower or duller minds, yet, I think, fundamentally just, fair, and kind to all. The systematic teaching at West Point ordinarily kept us closely to the text of each lesson, but there were memorable occasions when it seemed to him worth while to add to the expositions of the book developments entirely unforeseen, leading us on and on and opening vistas wholly unsuspected. It was done with a neat precision of method, so simply as to produce a delighted surprise when we suddenly found the somewhat arid formulas of the text leading straight to broad and general views. In our daily work we were kept closely to our allotted tasks, and it was always easy to see that he was able, but it was on such exceptional occasions that we knew that he was great. And

it was then that we had our first knowledge of the meaning of science, its insights and previsions. A teacher of this power is a light to his pupils, and they owe him a deep gratitude. I think this power of his was felt by all as great, even when it was not fully comprehended or appreciated. His weight and authority as a teacher were measured by his highest powers, not by the average of every day.

It is a privilege to quote a paragraph from a letter of Gen. Henry L. Abbot, Corps of Engineers, U. S. A., a pupil of Bartlett in the class of 1854. General Abbot writes:

> He was one whose influence upon the older graduates of the academy had few equals and whom we all remember with profound respect. His professional writings did honor to West Point. Personally I have never forgotten his interest in promoting my efforts to establish a suitable Engineer School of Application at Willets Point. He loaned me a full set of instruments for our little astronomical observatory from among those that had been replaced at the academy, and gave me much good advice about how to supplement the instruction received at the Military Academy. His interest in his pupils followed them in their life work.

LIFE AT WEST POINT.

An intimate picture of the simple life at West Point in the years 1840–1856 is given by Mrs. Théophile D'Orémieulx in the Bulletin of the Association of Graduates, U. S. Military Academy, No. 3, 1903, pp. 39–46. Captain D'Orémieulx was instructor of the French language at the academy for many years, an intimate friend of General Scott and a man of birth and culture. He was one of the founders of the West Point Army Mess, a social center; of an amateur orchestral club (where Beethoven's trios, and even Schumann's quintette, were played), and of other clubs and societies. Many of the officers' families kept but one servant at that time, or at most two—a cook at $8 per month and a maid at $4 or a little more. The Thanksgiving turkey cost 12½ cents per pound, eggs 23 cents a dozen, partridges 63 cents a brace (this was in 1853, the golden age). All lived under the same rule; there was no attempt at show; all were on the same social level, though the superintendent (then General Robert E. Lee) and the academic board of professors were older, of higher rank, and

were naturally deferred to. Official and personal visits were punctiliously paid.

The river was crossed by rowboat, or on the ice, or not at all. New York was reached by the Hudson River Railway or by steamboat. The social life was necessarily confined to the post, and to the neighboring villages of Garrison, Highland Falls, and Cold Spring. At Cold Spring Mr. Gouverneur Kemble lived, and once a week, on Saturdays, he kept open house for the professors and higher officers, and for distinguished guests from all over the country. Regularly every Saturday Professors Mahan, Bartlett, and Church crossed in a rowboat to Cold Spring, there to dine, to play whist, and to return at night. No one of the academic board was a member of the Century Club, as most now are. New York was too far away. These details throw some light on the simple and dignified life at West Point. It was not an idle life by any means. All the preparation for lessons and lectures that is exacted of professors and instructors at colleges was part of the daily work here, besides an infinity of details relating to the conduct and proficiency of cadets (the marking system is an integral portion of West Point methods). This was the atmosphere in which Bartlett lived for so many years. There was plenty of work, but little competition. Thoroughness was the essence of the instruction given. The justice of the discipline was absolute, or at least was so regarded by the cadets and officers of my own time (1866–73). We were, if not all a happy family, at least a self-respecting one.

THE MEMOIR ON RIFLED GUNS (1866).

In Ordnance Notes, Nos. 148 and 291, February 8, 1881, and April 18, 1883, Major George W. McKee, Ordnance Department, has papers under the title "The practical application of Bartlett's formulas to problems in gun construction," in which Professor Bartlett's analysis of the Parrott system of rifling is extended to cover the system then in use. Several of Bartlett's deductions are confirmed by calculation from data not available to him in 1866, and his practical suggestion as to the shape of the cutting tool in Benton's pressure gauge has been adopted in the Department.

Through the kindness of Brigadier-General William Crozier, Chief of Ordnance, Major Edward P. O'Hern, of the Department, has made a complete analysis of Bartlett's memoir in the light of all our present knowledge, which is printed in what follows. It must be borne in mind that the forty-five years that have elapsed since the appearance of Bartlett's memoir have been filled with the most elaborate researches on the subject, both theoretical and practical, at the hands of experts all over the world.

Summary of paper by Professor William H. C. Bartlett, U. S. Military Academy, entitled "Rifled Guns," published in Memoirs of the National Academy of Sciences, Vol. I, 1866: by Major Edward P. O'Hern, Ordnance Department, U. S. Army.

Professor Bartlett's paper entitled "Rifled Guns" is divided into two general parts. Part I discusses the strains to which rifled guns are subjected and Part II discusses the materials and dimensions of guns. The paper was published soon after the general introduction of rifled guns, and is probably one of the earliest scientific discussions and determinations of the stresses due to the introduction of the rifling. By the application of his formulas to a concrete example of the form of rifling then in use he demonstrated that the additional stresses due to the rifling were of a minor character in comparison with those that existed independently of the rifling.

Part I comprises a statement of the benefits derived from the introduction of rifled guns, a discussion of the additional strains due to the rifling, and of the fundamental principles that should govern in the design and use of guns, and a plea for the adoption of a uniform and safe system of artillery.

The general discussion is followed by the deduction of the formulas and by their application to specific problems.

The equation of the rifling curve for the twist used in the Parrott rifles, the most common type then in use in the U. S. service, is deduced in a clear, simple manner. This is followed by a very skillful mathematical deduction of two equations expressing the relation between the linear and the angular accelerations in terms of the velocity of the projectile, and of the elements of the rifling curve. By means of these equations the total longitudinal and torsional stresses due to the presence of the rifling may be computed. From a third equation may be computed the total stress tending to rupture the gun tangentially.

The formulas are applied in a number of interesting examples. The first is the determination of the total tangential, torsional, and longitudinal strains to which a 100-pounder Parrott gun was subjected in

firings under certain specified conditions. In that determination there are certain errors whose presence is a little difficult to understand. The most serious of these is that the tangential stress was computed not at the time of the maximum powder pressure, but after the projectile had traveled one-third the distance down the bore, at which point the pressure was assumed to be one-third the maximum pressure. Having thus obtained the total values of the forces, a direct comparison of their amounts was made without inviting attention to the fact that the areas of metal engaged in resisting the forces were different in the case of the tangential stress as compared with the others. In deducing the equation for the longitudinal strains and in his discussions and application thereof, Professor Bartlett makes no reference to the very important stresses due to the acceleration of recoil. This omission can be explained on the ground that he was discussing only the additional stresses due to the use of the rifling, but the failure to refer to the existence of the other stress appears remarkable in view of the fact that the gun to which he applied his formulas was mounted so as to recoil.

In the computation of the work with which the projectile and powder charge leave the gun there is an error in assuming that the center of mass of the gas moves with the same velocity as the projectile; whereas until the projectile has left the bore it moves with approximately one-half the velocity of the projectile, and after that instant moves with much higher velocity, usually assumed as approximately twice the velocity of the projectile

Computation of the work of friction is seriously in error in failing to include therein the friction on the driving edge of the lands, and the friction between the rotating band and the bore due to the action of the powder pressure in expanding a lip on the band, or in forcing forward the band on a coned surface in order to expand it into the rifling, as was necessary with muzzle-loading rifles.

Professor Bartlett proves by a mathematical analysis that on account of the energy of the moving parts the pressures registered by the crusher gauge then in use were probably much higher than the true values. His conclusions have since been fully verified by experiment, and have led to modifications in pressure gauges with a view to avoiding that source of error.

Part I concludes with a discussion of the friction developed between a projectile and its bursting charge and the resulting tendency to cause a premature burst by the ignition of the bursting charge.

Part II is a skillful mathematical analysis of the laws of transmission through the walls of a gun of the stresses resulting from the powder pressures. Professor Bartlett demonstrates that with the quickly acting black powders then in use the maximum pressure might be developed so quickly that the interior of the gun would be damaged before receiving proper assistance from the outer parts. The deduction

was based upon the assumption that the velocity of transmission of the molecular resistance was the same as the velocity of sound transmission in the gun metal. He reaches the conclusion that a gun having its dimensions adjusted to slow powder might fail under the action of quicker powder, and recommends the use of slow powders

His conclusion and recommendation are very sound He fails, however, to mention the important advantage of the slower powder, in that the same muzzle velocity may be secured with a less maximum pressure, due to the greater movement of the projectile before the time of the maximum.

ACTUARIAL DUTIES (1870–1893).

In the last years of Professor Bartlett's service at the Military Academy (1870-71) his attention was invited to actuarial questions then interesting the authorities of the Mutual Life Insurance Company of New York City. With the assistance of his colleague, Professor Church, Bartlett made an investigation and report upon these matters which led to the proposal on the part of the company that he should retire from active duty at West Point to become actuary of the company at a salary (one that was, I believe, subsequently increased) more than double his army pay. After some hesitation, Bartlett consented to break away from old associations and ties and to begin at the age of 67 years an entirely new life of labor and responsibility.

He was most successful in his new office, and to the surprise and pleasure of his friends took on a new lease of life and vigor. He continued as actuary of the company until 1889, when he retired at the age of 85, and lived happy and honored till his death, at his home in Locust Hill avenue, Yonkers, in 1893, aet. 89. Some of his actuarial work was printed by the company, but when, on taking charge of the academy library in 1901, I sought for a complete collection of the printed works of my old teacher, it was found to be impossible to obtain all of them, even from the officials of the company. The library contains only his interest tables, a quarto volume. Much of his work was, of course, never printed, as it was of a confidential nature.

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CYRUS BALLOU COMSTOCK

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BY

HENRY L. ABBOT

PRESENTED TO THE ACADEMY AT THE APRIL MEETING, 1911

CITY OF WASHINGTON
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Of the biographical memoirs which are to be included in Volume VII, the following have been issued:

WASHINGTON, D. C.
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CYRUS BALLOU COMSTOCK.

General Cyrus Ballou Comstock was born at West Wrentham, Massachusetts, on February 3, 1831, being the son of Nathan and Betsey (Cook) Comstock. He represented the ninth generation of an old New England family, which came originally from Devonshire, England, but the exact date of emigration is not of record. Late in life he compiled and published a biographical register of the family, from which it appears that the first of the name, William Comstock, probably removed from Massachusetts to Connecticut in 1635 or 1636, and made his home at New London, where he lived to a good old age. The Wethersfield records indicate that he took part in the expedition which captured the Pequot fort at Mystic in May, 1637, killing some five hundred Indians. The next four generations of the family resided in Rhode Island, but the General's great-grandfather, Nathan Comstock, removed to West Wrentham, Massachusetts, which has subsequently continued to be the home of his branch of the family. Nathan was a Quaker, and consequently took no active part in the Revolution, but he was a member of the Massachusetts convention which ratified the Constitution of the United States on February 7, 1788, and was also a member of the general court of Massachusetts in 1789.

The General as a boy studied in the local public schools and at an academy in Scituate, Rhode Island. Happening to see the operations and instruments of a party making a railroad survey, and those of a coast survey party, then occupying the primary station at Beaconpole, he became deeply interested in such work; he sought and obtained employment as rodman and as leveler on the Providence and Worcester Railroad and on the South Shore Railroad of Massachusetts. Nominated by the Hon. Horace Mann as cadet at the West Point Military Academy in 1851, he was graduated with first honors in 1855, receiving a commission as brevet second lieutenant in the Corps of Engineers. He served through all grades in that corps to that of colonel, inclusive, being retired from active service by

operation of law in 1895. In 1904 he was promoted to the grade of brigadier general on the retired list, under the act of Congress granting such advancement for military service during the Civil War. He died at New York City on May 29, 1910, and his remains were interred with military honors at West Point by the side of his wife, Elizabeth, daughter of Montgomery Blair. Their marriage had taken place in 1869 and her death and that of their infant occurred in 1872. The loss was a life-long grief to him.

Prior to the outbreak of the Civil War he served on the construction of fortifications in Florida and Maryland until assigned as assistant professor of natural and experimental philosophy at the Military Academy, where he remained from September, 1859, until July, 1861.

He was engaged in the construction of the defenses of Washington until the opening of the peninsular campaign when he was assigned to the engineering staff of the Army of the Potomac, and so continued until after the battle of Chancellorsville, serving as chief engineer from November, 1862, until March, 1863. He was then transferred to the Department of Tennessee, and under General Grant took part (after Captain Prime's health failed) as senior engineer at the siege and surrender of Vicksburg, continuing on the general's staff until himself invalided in September. The Government is now erecting in the Vicksburg National Park several tablets to commemorate the services of officers in the siege, and one of General Comstock is among them. It consists of a portrait relief mounted on a granite slab, with an inscription below, surrounded by a wreath border of laurel

He soon recovered his health and returned to duty, with the increased rank of lieutenant-colonel, as assistant inspector general of the Military Division of the Mississippi. On March 29, 1864, he was appointed senior aide-de-camp to Lieutenant-General Grant, retaining the volunteer rank of lieutenant-colonel, and served in that capacity to the end of the war, being engaged in the battles of the Wilderness, Spottsylvania, Cold Harbor, Petersburg, and in the assault and capture of Fort Harrison. He was temporarily detached to accompany General Terry as his chief engineer at the capture of Fort

Fisher in January, 1865, and again to serve as senior engineer on the staff of General Canby in the Mobile campaign of February, March, and April. He received on the spot from the Secretary of War, who arrived on the day after the taking of Fort Fisher, the brevets of colonel and brigadier general of volunteers. General Terry in his report states: "To Brevet Brigadier General C. B. Comstock, aide-de-camp on the staff of the lieutenant-general, I am under the deepest obligations. At every step of our progress I received from him the most valuable assistance. For the final success of our part of the operations the country is more indebted to him than to me." For his services in the Mobile campaign he was breveted major general of volunteers. During the war he received four brevets in the Regular Army, the highest being that of brigadier general, and attained the rank of major in the Corps of Engineers.

When the war was over, General Grant so highly appreciated his efficiency that he was retained on his staff with the volunteer rank of lieutenant-colonel until May 3, 1870, at which date he resigned it, and returned to duty as major in the Corps of Engineers, attracted by the offer of the superintendency of the Geodetic Survey of the Northern and Northwestern Lakes, tendered him by General Humphreys, who was cognizant of his eminent fitness for the position. As noted above, this duty was directly in line with his early ambition.

The lake survey had been inaugurated in 1841, and had been directed successively by six officers of engineers, serving for comparatively short periods; among them may be named General George G. Meade, then captain of topographical engineers. The operations were conducted with all the precision needful to determine not only the topography and hydrography of a region some 17,000 square miles in area, but also to be of value in estimating the form and dimensions of the earth. This involved the determination of standards of extreme accuracy, the measurement of eight primary base lines, a primary triangulation, covering about 1,650 miles in length, and hydrography extending over nearly 10,000 square miles. The local amount and direction of the earth's magnetic force and the local deflection of the plumb line were also matters to be

investigated. General Comstock was able to bring to a successful termination the grand features of the survey, and his final report stands as a monument to the professional ability of himself and of his associates. It should be added, however, that the work still continues and probably will never cease, in view of the enormous extension of lake commerce and the necessity of noting the changes in hydrography due to ice movements and other natural forces, and of keeping the maps for navigators always up to date. The General remained in charge of the work from 1870 to the completion of the primary triangulation in 1882, with only two intermissions; the first of about six months, when he was sent to Europe to examine the works of improvement at deltas of great rivers, and the second for about a year, when on leave of absence in Europe with similar objects in view. During this long period he also served on several temporary boards to report on technical lake-harbor problems and on the improvement of low-water navigation on the Mississippi River, and he also acted as superintending engineer to examine the progress of Eads' jetties at the mouth, upon which he rendered six reports in 1875-1877.

His next important assignment was to the Mississippi River Commission, which was created by act of Congress, approved June 28, 1879. He was detailed at once as a member, and continued to serve on it for sixteen years until his retirement from active service in 1895, being its president for the last five years. Many difficult hydraulic problems, and some legal in character, came before the board for consideration, and General Comstock's record met the approval of those most conversant with such matters.

After August 2, 1882, he was also a member of the permanent board of engineers for fortifications and river and harbor improvements, where our official relations were most intimate, leaving many pleasant memories. In addition to these board duties he served as division engineer of the Southwestern Division after December, 1888, and he commanded the Engineer School of Application, then stationed at Willets Point, New York Harbor, for about a year, in 1886-1887. He represented the War Department at the Fifth Congress of Inter-

national Navigation, held at Paris in July, 1892. Such were his final duties before retirement.

General Comstock's busy life was spent in the application of science to public needs rather than in original research, except incidentally when practical problems arose in his works; but his interest in the advancement of science was so great that in 1907 he donated to the National Academy of Sciences the sum of ten thousand dollars to create a trust fund, of which the interest is to be devoted to researches in electricity, magnetism, and radiant energy. His own experience had led him to appreciate the value of such studies. He was elected a member of the Academy in 1884, and was also a member of the American Academy of Arts and Sciences and of the Military Order of the Loyal Legion.

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General Comstock's writings were largely confined to technical projects for local river and harbor improvements, and the annual reports of the chief of engineers contain fifteen papers of this character from his pen. Furthermore, besides the numerous reports of the permanent boards of which he was so long a member his signature appears upon the reports of sixty local engineer boards, of twenty-one of which he was president. To recapitulate these numerous documents is needless, but the following may be named:

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Three papers in the series of ten Public Documents Relative to the Scientific Surveys of the United States, and to the report thereon made by the National Academy of Sciences, in accordance with the requirements of the Act of Congress, approved June 20, 1878.

Variation in length of a zinc bar at the same temperature. American Journ. Sci., 3d ser., Vol. 22, 1881, pp. 26–30.

Mississippi River. Encyclopædia Brittanica, tenth edition.

Report on the Fifth Congress of International Navigation, held at Paris, July, 1892.

Note on "change of plane" at Red River Landing. Annual Report of the Chief of Engineers for 1893, Part V, Appendix YY, Report of the Mississippi River Commission, Appendix 1, pp. 3564–3569.

A. W. Johnson

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VII

BIOGRAPHICAL MEMOIR

OF

SAMUEL WILLIAM JOHNSON

1830-1909

BY

THOMAS B. OSBORNE

PRESENTED TO THE ACADEMY AT THE APRIL MEETING, 1911

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WASHINGTON, D. C.
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1911.

SAMUEL WILLIAM JOHNSON.

Samuel William Johnson was born in Kingsboro, New York, July 3, 1830, the fourth child of Abner Adolphus and Annah Wells (Gilbert) Johnson. His ancestry traces back in every line to early colonial settlers in Connecticut. He studied in the district schools and the academy at Lowville, New York. He then alternately taught and studied in this country, Germany, and England until 1855, when he began his active service of forty years as a member of the faculty of the Yale (now the Sheffield) Scientific School. He was director of the Connecticut Agricultural Experiment Station from 1877 to 1900. He was early a member of the American Association for the Advancement of Science, and was chairman of its subsection on chemistry in 1875. In 1866 he was elected a member of the National Academy of Sciences. He was an associate fellow of the American Academy of Arts and Sciences. He was long a member of the American Chemical Society and was its president in 1878. He was one of the original members of the American Association of Official Agricultural Chemists, was its president in 1888, and was also president of the American Association of Agricultural Colleges and Experiment Stations in 1896. He died at his home in New Haven July 21, 1909.

Professor Johnson's life was a striking example of the power of a dominant purpose conceived in boyhood and consistently followed to old age.

The Experiment Station Record, in an editorial, said that

his name will be intimately linked with the early history and the development of agricultural science in this country, as it will be with the establishment of the agricultural experiment station as an American institution. He was a pioneer of pioneers, a leader of thought, the disciple of a new idea of science. He gave not only results, but an intelligent understanding of their meaning and application; and in the early days of the new work he aroused an interest and confidence in it which went far toward making possible its spread and development. The career of this man is a monument to industry and to untiring devotion in behalf of a cause which appealed to him from his youth. As a teacher of agricultural teachers, as a leader in agricultural science, and as a

father and promoter of the movement to bring the sciences to the aid of the farmer through the experiment stations, he rendered signal service to the cause of agricultural advancement, and has left a name to be remembered with great honor

Although Professor Johnson's childhood was spent on a farm far removed from any scientific influences, he early acquired a keen interest in the scientific side of the processes of plant and animal life, by means of which all with whom he was associated were gaining support for their families. He thus as a child became impressed with the importance and dignity of agriculture, to the promotion of which he devoted the whole of a long and active life, contributing by his lectures and publications concerning the fundamental principles of agriculture not only to the development of the art, but also to the intellectual life of the farmer.

His attention seems to have been first directed to such subjects by his father, to whom, as his "earliest and best instructor," he dedicated his first book. Although his father had no scientific training he had an inquiring mind, which led him to think about and to discuss the wonders of life in such a way as to impress profoundly the child who was his constant companion. The interest thus awakened was soon directed into purely scientific lines by the influence of David Mayhew, one of his first teachers at the Lowville Academy, to which he was taken when only ten years old by his older brother. Mayhew, who was a man of more than ordinary ability and scientific training for that time, soon excited in the boy a strong interest in chemistry, which he at once began to study with energy and to apply to the solution of agricultural problems.

That he was destined to become a teacher of agricultural science, and especially of agricultural chemistry, is shown by his first paper, entitled "Fixing ammonia," which was published when he was but seventeen years old. This paper is remarkable, as it shows the purpose which dominated his whole after life and the character of the education which he had acquired under what would now be regarded as unfavorable conditions, and is not only characteristic of his later writings but interesting as one of the early contributions to American agricultural science.

During his school days he was not content with the facilities provided by the academy for acquiring a knowledge of chemistry, and at the age of sixteen he fitted up a room in a wing of his father's house as a laboratory. Here he prepared the reagents necessary for qualitative analysis, according to the direction given in an edition of Fresenius which his teacher had presented to him. He thus gained experience in conducting chemical work without the assistance of instructors, developing a degree of self-reliance which had a marked influence on all of his later life. An interesting picture of the work that he did in this laboratory is given by his first note book, which contains an account of successes and failures in the many processes which he conducted. The entries in this book show that it was no boy's work which he had undertaken, for the experiments described were intelligently planned to supplement the instruction that he received at the academy.

After teaching school for two or three years he determined to continue his study of chemistry with the intention of devoting himself to its application to agriculture. Unlike other students of his time he made his choice of instructors in the spirit of the modern university student. He did not seek an institution where he could follow a prescribed course and obtain a degree, but applied himself to getting information as to the men who would give him the most of what he sought for.

After a careful canvass he determined to place himself under the instruction of J. P. Norton, then professor of scientific agriculture in Yale College. Accordingly, in the winter of 1849-1850, he went to New Haven, where he studied during the following two years. There he came under the influence not only of Norton but of the Sillimans, father and son, J. D. Dana and others, by all of whom he was appreciated and encouraged.

His life in New Haven was a busy one, for in addition to his study he was compelled to devote some time to commercial analytical work in order to meet his necessary expenses, as his father was at first inclined to do but little to help him.

In the spring of 1853, with the approval and assistance of his father, he went to Leipzig, where he worked with Erdmann and Neumann for nearly a year, chiefly at organic and inor-

ganic analysis. He then went to Munich, where he spent the next year in Liebig's laboratory, receiving instruction in organic chemistry, especially in its relations to plant and animal life. He also attended the lectures of Pettenkofer and Von Kobel on physiological chemistry. Von Kobel and Liebig contributed much to his social and literary development. He was a frequent visitor in their houses, where he learned the habits of German society, and during his later years he often recalled with pleasure the social evenings he thus spent with their families and friends, and many of the habits of manner and speech which he then acquired were retained throughout his life.

After a brief stay in Paris, where he visited the laboratories of prominent chemists, he went to England to work in Frankland's laboratory for a few months in order to learn the methods of gas analysis.

Having visited the experimental farms of Lawes and Gilbert and other places of agricultural interest, he hurried back to New Haven to take charge of the Yale Analytical Laboratory. While in Europe his efforts were directed to qualifying himself for a teacher of agricultural science, and his hopes were centered in plans for establishing at some place in this country an institution where instruction in the principles of this art should be taught. In connection with such plans he had extensive correspondence and many interviews with Evan Pugh, who was then studying with the same objects in view and who later became head of the College of Agriculture of Pennsylvania.

These plans were changed by his appointment as first assistant in charge of the Yale Analytical Laboratory, but the purpose of his life was not altered thereby. The next year he was made professor of analytical chemistry and the year after professor of analytical and agricultural chemistry in the Yale Scientific School. Having thus at last obtained a position in his chosen field, he set himself at work to develop a popular interest in scientific agriculture by means of essays and lectures. For many years he made frequent and regular visitations all over New England and at times into New York State, attending meetings of agricultural societies and farmers' clubs.

He was the apostle of a cause, and his earnestness, sincerity, and clearness as a lecturer rendered him and his subject popular among his hearers and secured for him the confidence of the agricultural community.

He was appointed chemist to the Connecticut State Agricultural Society in 1856 and made his first report in 1857. This report is of much interest, as it was the first agricultural publication of its kind issued in this country. In it he employed many of the methods which are still used in similar reports issued by the agricultural experiment stations of the United States. Thus he placed a money value on the commercial fertilizers which he analyzed, based on the cost of their essential elements as derived from the market value of such substances in their cheapest form available for agricultural purposes. He also discussed the manurial value of the several fertilizers from a scientific standpoint in so simple and concise a manner that all farmers of ordinary intelligence could easily understand their value in practice and the principles involved in their economical application.

This report was much more than a chemist's statement of analytical results and has had a lasting influence. It instructed the farmer in many things of great practical importance to the proper conduct of his business and set a standard for those who have since been engaged in the application of science to agriculture. One cannot fail to recognize in this report the beginning of the movement which later led to the establishment in every State of the agricultural experiment stations, which are now filling such an important place in the development of American agriculture. We can fairly say that Professor Johnson was himself the first agricultural experiment station in this country.

The work that he thus began he continued with untiring persistence until the outbreak of the Civil War, in spite of the many official duties which his college teaching involved. Lack of funds and diversion of public interest brought the activities of the Connecticut Agricultural Society to a close, and consequently his efforts in this direction ceased for the time being.

During the fall of 1859 he delivered at the Smithsonian Institution in Washington a series of lectures on agricultural

chemistry, which attracted wide attention among those interested in the subject, and served as the basis of his most successful book, "How Crops Grow," which was published eight years later. During these eight years he contributed many articles to agricultural journals and numerous scientific papers to the American Journal of Science and Arts. He translated and edited Fresenius' Qualitative Analysis, wrote "How Crops Grow," and discharged his duties as professor of analytical and agricultural chemistry in the Sheffield Scientific School, into which the Yale Chemical Laboratory had been merged.

The war being over and public attention again turned to the pursuits of business, he, with others who had been active members of the Connecticut Agricultural Society, succeeded in establishing a board of agriculture under the authority of the State. By this board he was appointed chemist, and at once resumed the work he had formerly done for the Agricultural Society.

This work he continued for the next ten years, and thereby demonstrated, in a practical manner, what an experiment station could do for the agricultural community. In the conduct of this work he devoted himself largely to practical questions rather than to purely scientific problems, as he hoped thereby to gain the interest and support of the community to the end that the State should establish and suitably endow an independent institution, which should furnish the farmer with such scientific information and investigations as he required for the successful conduct of his farm.

A step in this direction was taken in 1875, when the legislature of Connecticut appropriated $2,800 annually for two years for experiments in agriculture to be carried on in laboratories which Wesleyan University offered to furnish free of charge. This work was done under the direction of W. O. Atwater, a former assistant of Professor Johnson, who was then professor of chemistry at that place. Thus through the continued efforts and as the direct outcome of Professor Johnson's work the first experiment station in the United States was established in his adopted State.

Two years later it was decided to place the work of the station on a permanent and established basis, and accordingly

the legislature incorporated the Connecticut Agricultural Experiment Station as an independent institution under the management of a board of control representing the agricultural and scientific interests of the State. Professor Johnson was at once appointed its director and remained in this position until he resigned, twenty-three years later.

In his conduct of this institution he accomplished a work of national importance, for the influence of his learning and high ideals was all-controlling in the development of the similar institutions which were later established throughout the country.

Under him were trained in experiment station work many younger men who have carried out plans and ideas which Professor Johnson evolved in his administration as director. His high standard of scientific work in its application to practice and his keen sense of fair dealing as between the farmers and those from whom they bought supplies have done much to shape the policies of all similar institutions and to win for them the respect of the entire community.

To the development of the analytical methods employed in the chemical work of experiment stations he contributed much, both in respect to their accuracy and rapidity of execution. His deep knowledge of chemistry and wide personal experience in almost every branch of chemical analysis rendered him especially fitted to develop this part of the work and, in connection with his profound interest in agriculture and his marked ability as a lecturer and teacher, made him an ideal director of a new institution which stood in need, not only of new and proper methods of work, but of the support and confidence of those whom it was designed to help.

Of the work which he thus accomplished his colleagues have written: *

> It has been said that the most substantial contribution of the United States to applied science has been in using chemistry for the improvement of agriculture. Of this movement Professor Johnson was the leader. The whole system of agricultural experiment stations may well be regarded as his monument.

* Report of the President of Yale University for 1910.

And again: *

Professor Johnson's broad and keen grasp of chemical problems, added to his farsighted appreciation of the many advantages to be gained by a judicious application of the science of chemistry to agriculture, made him a power in his generation, and his services counted for much in the development of agricultural chemistry and the inauguration of the Agricultural Experiment Station, which today is a recognized feature of practically every State in the Union

In the early years of the Sheffield Scientific School he was a pillar of strength, an example of the highest type of productive scholar, and a forceful illustration of the power which a scientific man can wield for the good of the community The life of Samuel William Johnson and the work he accomplished constitute a suggestive example of a form of high public service which the man of scientific training can render his country and humanity.

Professor Johnson's most important work was in his chosen field of agricultural chemistry, but he accomplished much in other directions. When he came to New Haven as first assistant in the analytical laboratory, opportunities for instruction in scientific subjects were limited, but soon after the large gifts of Joseph E. Sheffield led to the organization of the Sheffield Scientific School. In the development of this school Professor Johnson took an active part, especially in the department of chemistry, in which he gave instruction first in analytical and agricultural chemistry and later in theoretical and organic chemistry. As a teacher and lecturer in these subjects he exerted a strong influence on his students, among whom were many who later achieved distinction in science and who remembered him as an inspiring teacher.

Of the part that he took in the work of the school his colleagues have said: *

As occasion demanded, he taught the different branches, analytical, agricultural, theoretical, and organic chemistry, and in all of these subjects he displayed profound knowledge and great familiarity with the literature. His teaching was clear, concise, and philosophical, and he was successful in imparting much of his own enthusiasm for science to his students. * * * His connection with the School added much to its reputation. He was prominent in chemistry, and he became famous from his writings and lectures upon agricultural science.

* Report of the Director of the Sheffield Scientific School for 1910.

As a student of chemistry he had few equals in his day. A born lover of books, he was an incessant reader of the works of others and his library was filled with books on every branch of science, all of which he had read with an interest and care that made him a master of many subjects. His love of reading was not confined to scientific subjects; he enjoyed poetry and general literature with equal intensity. From the day he left home to begin his life work to the day of his death he was a constant buyer of books. When he returned from Germany he brought with him a library of chemical journals and standard treatises such as few chemists now feel that they can afford to own. Although his means were always limited, he was never too poor to buy books, and all his life denied himself many pleasures that he might have at hand the books he wanted. In his later years, when feeble health and failing sight made much reading impossible, his greatest sorrow was his inability to keep in touch with the enormously increased chemical literature.

As an author he made an impression, not only on his fellow scientists, but on the general public, by a clear and concise style which was not the result of cultivation and training, for his first paper, published when he was but seventeen, was written in the same simple and finished style that was characteristic of all his later writings.

For more than fifty years he was a constant contributor to agricultural and scientific journals. Although his publications were numerous he wrote few books. Two of these, however, were very successful, namely, "How Crops Grow," published in 1868, and "How Crops Feed," published in 1870. These books were the first printed in this country which brought together the data scattered through the literature relating to the composition and physiology of plants. They furnished a new basis for instruction in agriculture and were more widely read than any books before published on agricultural chemistry. They were translated into German, Russian, Swedish, and Japanese, and the former into Italian and French also.

In 1891 he prepared a new edition of "How Crops Grow," and even today the sale of both these books is not inconsiderable. In 1864 he edited Fresenius' Manual of Qualitative

Chemical Analysis, a second edition in 1875, and a third edition in 1883. In 1868 he published a book entitled Peat and its uses as Fertilizer and Fuel, and in 1870 he edited Fresenius' System of Instruction in Quantitative Analysis.

Of his influence as an author one of his colleagues has written that: *

He was a teacher through the written word He understood well how to make effective the work and writings of others, as well as his own, and this gave to his writings a breadth of view which was especially valuable at the time.

As an investigator his name does not appear prominently in the literature, for his chief efforts were directed to securing the means through which investigations have since been made by others. His many duties and limited resources afforded him scant opportunity for purely research work; nevertheless he found time for not a little work along these lines, and under his direction and with his aid much work of this kind was carried out by his students and assistants, to whom he generously granted the privilege of publishing under their own names. In the conduct of such work he was more interested in the training and development of the younger men than in securing credit for himself, and therefore his practice was to make his associates feel that the work which he assigned to them was their own, and that the responsibility for its success rested on them. It thus happened that many problems which he might fairly have claimed for his own study he assigned to others, in order that they might learn the methods of scientific research by assuming the responsibility for the conduct of details. During the progress of such work he was always eager to aid by suggestion and criticism, but patiently refrained from interference unless called on for advice. His part in the progress of research is, in fact, much greater than appears on the record, and many younger men owe much to him for the start he gave them in their scientific careers. His desire was to train men to be investigators rather than to appear as one himself.

* Experiment Station Record, Vol. 21, 1909, p. 206.

As an expert in many important cases in court he showed great ability and won a high reputation among the legal profession. The profound knowledge which he brought to bear on these cases, the care and accuracy with which he performed the analytical work involved, the thoroughness with which he prepared every detail, and the clear and logical way in which he set forth his conclusions, have many times been recounted to the writer by leaders of the bar, and have always been accompanied with expressions of the highest admiration and respect for the ability he displayed.

As a man Professor Johnson had a most attractive personality which endeared him to all who were intimately associated with him. His kindly interest in his students and assistants and his many generous and helpful deeds in their behalf will long be remembered by those who had the good fortune to work with him.

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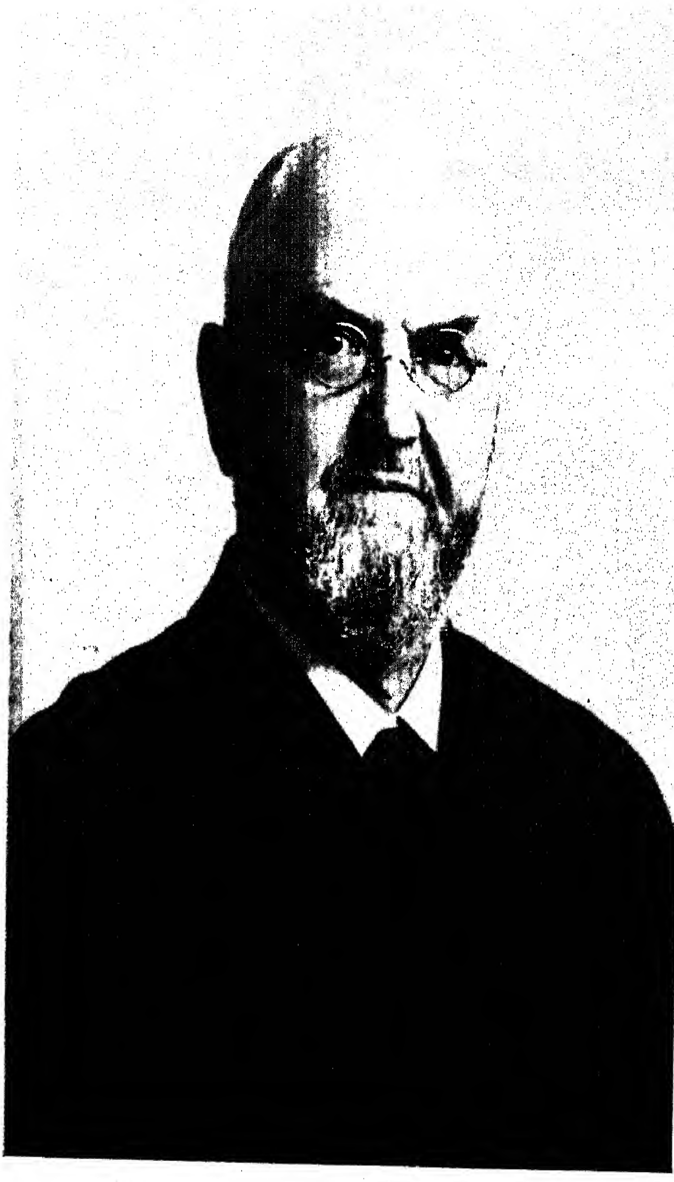

Charles A. White

NATIONAL ACADEMY OF SCIENCES
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BIOGRAPHICAL MEMOIR

OF

CHARLES ABIATHAR WHITE

1826-1910

BY

WILLIAM H. DALL

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Of the biographical memoirs which are to be included in Volume VII, the following have been issued:

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CHARLES ABIATHAR WHITE.

The first American ancestor of the subject of this memoir was William White, of Boston, Mass., who settled at what was then called Windmill Point, about 1640. William's grandson, Cornelius White, purchased a tract of land in Taunton, Mass., as a homestead, part of which extended within the adjacent town of Dighton. Here Cornelius moved about 1700, and successive generations bearing the name have owned and occupied the farm ever since. So attached to their home were the members of the family that, according to the notes of Doctor White (which have been largely utilized in preparing this memoir), for five generations no member of the family ever strayed fifty miles from the original homestead. In the local public affairs of their community, however, they are recorded as having taken an active part. The great-grandfather of Dr. White, Cornelius White, was a captain of militia during some of the colonial wars of his time, and on the breaking out of the war of independence was made a member of the "Committee of Inspection, Correspondence, and Safety," organized to promote the patriot cause. His son, Cornelius, junior, though barely twenty years old, enlisted in the Revolutionary forces immediately after the battle of Lexington. After the success of the struggle both returned to their Dighton farm. Abiathar White, son of Cornelius White, junior, married Nancy, daughter of Daniel Corey, of Dighton. Their second son, born at Dighton January 26, 1826, was named Charles Abiathar and is the subject of this memoir.

In 1838 the family removed to settle at the site of Burlington, in the Iowa Territory. There, subject to the hard conditions of pioneer life and with small and irregular opportunities for education, the boy grew to manhood. Doubtless the bias toward the study of nature was inborn, but the life in a new country full of birds and animals differing from those to which he had been accustomed in earlier years in Massachusetts must have been full of interest to the youth entering on his teens. The richness of the rocks of the region in well preserved and

attractive fossils may well have been a stimulus toward the career on which he finally entered.

On attaining his majority in 1847 he revisited the east and the following year was married to a schoolmate of his childhood, Charlotte R. Pilkington, daughter of James Pilkington, of Dighton. This union proved ideal, and nearly fifty-four years of happy married life was granted them before the death of the beloved wife and mother, July 16, 1902

His eastern travel and experiences, meeting with the scientific men of the day, greatly stimulated his inherent love of nature. He returned with his young wife to Burlington in 1849, and then began a systematic study of the natural history of the region in which he lived.

In those days, when a purely scientific career was almost unknown in America and reserved for those whose financial situation rendered them more or less independent, the inevitable resource of the average student was found in the study and practice of medicine

He began his studies a few years after his return to Iowa, entering, as was then the practice, the office of S. S. Ransom, M. D., a leading practitioner, as a medical student. Having been known to his preceptor since boyhood, he received cordial aid and encouragement in his studies. These were followed by one full course of lectures in the Medical School of Michigan University and a period of study in the Rush Medical College of Chicago, which is now the medical department of the University of Chicago. Here he received the degree of doctor of medicine. His studies in geology and on the fossils of Iowa became known to Prof. James Hall, of Albany, state geologist of New York, who induced him to accept a position as his assistant, which Dr. White held during 1862 and 1863. As with most of the assistants and pupils of this masterful and eager paleontologist, friction developed in the course of time, and in 1864 Dr. White returned to Iowa and entered upon the practice of medicine at Iowa City.

The desirability of a geological survey of the state had become evident to progressive citizens of Iowa, and in 1866 such a survey was established by the legislature. Dr. White received the appointment of state geologist and entered upon his

duties in this capacity in April, 1866 The survey continued for four years, issuing two volumes of reports on the economic and structural geology, but came to an end by the failure of the legislature to appropriate funds for its support, in 1870.

In 1866 he received the honorary degree of master of arts from Iowa College, and in 1867 was appointed to the professorship of natural history in Iowa State University, giving part of his time to the university during the continuance of the state survey, and afterward taking up the whole duty of the professorship. In 1873 he accepted a call to a similar professorship in Bowdoin College, and removed with his family to Brunswick, Maine.

In addition to his college duties, at the request of Lieut. G. M. Wheeler, U. S. A., in charge of the government surveys west of the 100th meridian, he undertook, in 1874, the publication of the paleontology of that survey

The activities of the various governmental surveys of that period, more or less in rivalry with each other as to the production of scientific results, afforded greater opportunities for research-work in those lines than ever before. An opening presenting itself for such work, far more congenial to him than teaching, led Dr. White to resign his professorship and join the U. S. Geological Survey of the Rocky Mountain Region, directed by Major J. W. Powell, in 1875. The following year he was appointed by Dr. F V. Hayden, directing the U. S. Geological Survey of the Territories, to complete and edit unfinished paleontological work left at the death of F. B. Meek, in 1876. He remained with the Hayden Survey until it was suspended in 1879. At this time he was appointed one of the salaried curators of the U. S. National Museum, in general charge of the paleontological collection.

In 1882 the geological work of the government was reorganized as the United States Geological Survey, under Clarence King as director, and Dr. White was engaged as geologist by the survey, continuing in its service until his resignation in 1892. During 1882 he was detailed as chief of a commission on artesian wells in the Great Plains, organized by the U. S. Department of Agriculture. After his return to his regular duties, he was requested by the director of the National Mu-

seum of Brazil to prepare a report on collections of Mesozoic fossils which had been made by members of the Brazilian Geological Survey. The report was published in the Archives of the Museum at Rio, in both Portuguese and English, in 1887.

Dr T W. Stanton, in a review of Dr White's work and his services to the U S. National Museum, prepared for the Annual Report, has the following remarks:*

During all the years of Dr White's service with the various government surveys his office work was done in the National Museum, where he was actively connected with the care and preservation of the collection of invertebrate fossils to which his field work so largely contributed He came to the institution at a critical period in the history of its paleontologic collections Professor F B Meek, who had long had charge of them, had recently died and new material was rapidly coming in from the various surveys and exploring expeditions in the western territories Dr White immediately took up the work of properly caring for the collections, at first unofficially and afterward as curator His intimate acquaintance with Professor Meek and his work, his knowledge of the subject and his systematic, painstaking habits enabled him to render invaluable service at that time Scattered types were recognized, catalogued, and fully labeled, those that had not been illustrated were figured, and the records and collections of the whole department were systematized. After retiring from the active duties of a curatorship he continued his connection with the National Museum as associate in paleontology

He was one of the founders of the Geological Society of America. The State University of Iowa conferred upon him in 1893 the degree of doctor of laws, *honoris causa*. He was president of the Biological Society of Washington during the years 1883 and 1884. He joined the American Association for the Advancement of Science in 1868, later becoming a fellow, and was elected vice-president for the section of geology in 1888. In 1889 he was elected a foreign member of the Geological Society of London.

After Dr. White's retirement from active service he employed his time partly in botanical studies and to some extent in popular and reminiscent contributions to periodicals. He prepared biographical memoirs of deceased friends, three of whom, Meek, Engelmann, and Newberry, were members of

* Ann Rept. U. S Nat Mus., 1910 [1911], p 72.

the Academy, and in similar ways utilized the time of waiting which comes to most men who pass three score and ten. Up to a short time before the end he was remarkably alert, active, and interested in the progress of his favorite branches of science.

He died June 29, 1910, in Washington, D. C, and his remains are interred at Rock Creek Cemetery. Of eight children four sons and two daughters survive him.

The character of Dr. White's life work can best be understood through an examination of the accompanying bibliography, in which, however, no attempt has been made to include fugitive papers in the daily or weekly press or other similar matter not of scientific importance.

In general he was engaged in pioneer descriptive work in paleontology and geology, which he did with care, precision, and clearness In his later works the attempt to treat his data philosophically is very evident. The mass of his publications is very considerable. Among those especially useful to later students are his summaries of American non-marine fossils and of American fossil Ostreidæ. He traveled extensively abroad and made the acquaintance of many foreign paleontologists, with whom he maintained friendly relations. Much of his correspondence and other papers and articles of interest are deposited in the State Historical Department of Iowa at Des Moines; as, though from 1876 a resident of the city of Washington, he preserved a sturdy pride in the state in which the formative period of his life was passed.

Dr. White became a member of the Academy in 1889. He was elected a corresponding member of the following scientific societies at the dates mentioned:

1880—Academy of Natural Sciences, Philadelphia.
1893—Geological Society of London.
1893—Isis Gesellschaft für Naturkunde, Dresden.
1893—R. Accademia Valdarnese del Poggio, Montevarchi, Italy.
1893—K K. Geologische Reichsanstalt, Vienna
1894—Kaiserliche Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher, Halle an der Saale, Germany.

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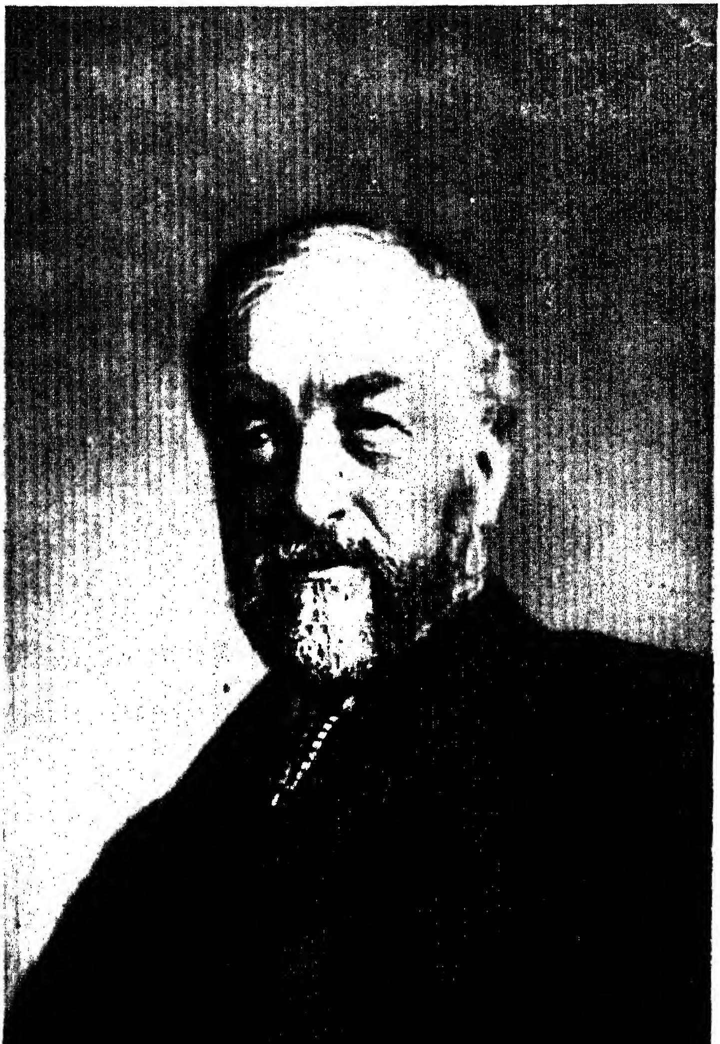

S. P. Langley.

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VII

BIOGRAPHICAL MEMOIR

OF

SAMUEL PIERPONT LANGLEY

1834-1906

BY

CHARLES D. WALCOTT

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1911

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Of the biographical memoirs which are to be included in Volume VII, the following have been issued

*

SAMUEL PIERPONT LANGLEY.[a]

Samuel Pierpont Langley, Doctor of Science and of Civil Law, was born at Roxbury (now part of Boston), Massachusetts, on August 22, 1834, and died at Aiken, South Carolina, on February 27, 1906 Mr. Langley won eminence by his achievements as an astronomer, especially by his astrophysical observations and discoveries, and he became known to the world at large through his eighteen years of administrative service as Secretary of the Smithsonian Institution His fame will also become increasingly greater as the new science of aviation—or aerodromics, as he termed it—is further and further developed, for to Langley belongs the honor of being the first to demonstrate to the world the practicability of mechanical flight with machines heavier than the air, sustained and propelled by their own power

Mr. Langley's boyhood and his young manhood, until the age of twenty-three, were spent in Roxbury and Boston. He was educated in private schools, in the Boston Latin School, and in the Boston High School, from which he was graduated in 1851. Led by an early taste for mathematics, he chose the profession of civil engineering and architecture, and in 1857 went West, where for seven years he successfully practiced his profession, chiefly in Chicago and St Louis.

In 1864, in company with his brother, John Williams Langley, he visited Europe and traveled for about a year, taking a keen interest in the work of the scientific institutions, the astronomical observatories, and the great art galleries of the Old World. The knowledge then acquired led, upon his return to Boston in 1865, to his appointment as assistant at the Harvard College Observatory, and in 1866 he became assistant professor of mathematics in the United States Naval Academy at Annapolis, chiefly for the purpose of reorganizing its small observatory. His reputation as a skillful astronomer was thus

[a] The draft of this memoir was prepared by Mr. A Howard Clark, of the Smithsonian Institution.

early established, and at the close of a year's service at Annapolis he was invited to fill the post of director of the Allegheny Observatory and professor of astronomy and physics in the Western University of Pennsylvania, where he remained for twenty years.

One of the most important achievements accomplished by Professor Langley while at Allegheny was the introduction of a system of standard time distribution to various cities and railroads, a work which he himself thus described about the year 1885, when time signals were being sent from Allegheny over 4,713 miles of railroad:

A mention of the observatory's work would be incomplete without some account of its system of time distribution introduced by the present director in 1869 Previous to that date, time had been sent in occasional instances from American observatories for public use, but in a temporary or casual manner.

The Allegheny system, inaugurated that year, is believed to be the parent of the present ones used in this country in that it was, so far as is known, the first regular and systematic system of time distribution to railroads and cities adopting it as an official standard. * * * For the benefit of any future writer of the history of the subject, it may be stated that in 1870 the Allegheny Observatory had already in extended operation the system of time distribution above described, that about 1873 the director at Cambridge Observatory, after conference with the writer, introduced substantially the same provisions for connecting Harvard College Observatory with the New England roads; and that about the same time the Washington Observatory, which had previously sent signals in a limited and desultory manner, commenced to do so in emulation of the new system.

It was at the Allegheny Observatory, aided largely by the income derived from the standard time service, that Professor Langley began the series of researches which have so greatly added to our knowledge of the sun.

As an astronomer, his work was devoted chiefly to original investigations relating to the physical nature and functions of the celestial bodies, rather than to measurements of time, distance, and position. As an observer at the eye end of an equatorial he was inferior to none, and his visual studies of the minute structure of the sun's surface have become classical. His beautiful drawing of the great sun spot of December, 1873, has not yet been surpassed in accuracy of detail, notwith-

standing the great improvements since made in instruments of observation.

In 1869, 1870, 1878, and 1900 he observed the total eclipse of the sun, and his account of the eclipse of 1878 from Pikes Peak is particularly notable.

Mr. Langley's distinction as a visual observer, however, was far exceeded by his valuable contributions to the study of solar radiation. In these studies, which he began as early as 1870, he employed the thermopile, but he became more and more dissatisfied with this instrument, on account of its slowness of response and the inadequacy of its sensitiveness to the measurements which he desired to make. His experiments with this instrument on the solar spectrum convinced him that something as much superior to the thermopile of those days as that was to the thermometer would be required before any satisfactory progress in this direction would be possible. From 1878 to 1880 he was engaged in various attempts to devise a more perfect instrument for measuring radiation, and he succeeded at length in the invention of the bolometer, an instrument now in world-wide use. With this instrument, essentially an electrical thermometer on the Wheatstone's bridge principle, changes of temperature of less than the hundred-thousandth of a degree Centigrade are measured; and, by special installation, differences in temperature amounting to one-billionth of a degree may be detected.

The investigations by Mr. Langley in radiation may be grouped under five heads: (*a*) The distribution of radiation over the sun's surface and in sun spots; (*b*) the solar energy spectrum and its extension toward the infra red; (*c*) the lunar energy spectrum and the temperature of the moon; (*d*) spectra of terrestrial sources and determination of hitherto unmeasured wave lengths; and (*e*) the absorption by the earth's atmosphere of the radiation of the sun, and the determination of the solar constant of radiation. In the first of these investigations he found that at 98 per cent of the radius from the center of the sun's disk, along both the polar and equatorial diameters, the radiation fell off one-half. Sun spots were found to affect the total radiation of the sun not more than one-tenth of one per cent. In the investigation of the

solar energy spectrum toward the infra red, Mr. Langley discovered evidences of solar radiation extending beyond all previously known wave lengths.* The temperature of the sun-lit moon he found to be a little above 0° Centigrade. His most interesting researches in terrestrial sources of radiation related to the light of the Cuban firefly, *Pyrophorus noctilucus,* which he compared with that of the electric arc and other sources of illumination. He proved the immense relative economy of Nature's source of light.

The last of the series of researches to be mentioned was the determination of (*a*) the absorptive power of the earth's atmosphere for solar radiation, and (*b*) the solar constant of radiation. In his preliminary study of this important subject he found that all previous estimates of atmospheric absorption were too low, and that all parts of the spectrum must be studied separately and in detail in order to determine from the solar radiation reaching the earth's surface the total amount of radiation which reached the outer limits of our atmosphere. He became so convinced of the great practical importance of this work to mankind in its relation to climate and life on the earth that in 1881, while at the Allegheny Observatory, he enlisted the aid of wealthy friends and of the United States Government to send an expedition to Mount Whitney, California, where exceptional opportunity would be afforded for the necessary observations.

In the introduction of the Mount Whitney report Mr. Langley says:

> If the observation of the amount of heat the sun sends the earth is among the most important and difficult in astronomical physics, it may be termed the fundamental problem of meteorology, nearly all whose phenomena would become predictable if we knew both the original quantity and kind of this heat; how it affects the constituents of the atmosphere on its passage earthward; how much of it reaches the soil; how, through the aid of the atmosphere, it maintains the surface temperature of this planet; and how, in diminished quantity and altered kind, it is finally returned to outer space.

In 1892 Mr. Langley introduced a continuous automatic photographic registering device to record the indications of the bolometer, and thus made it possible to map in a few

minutes the whole energy spectrum of the sun in a manner adapted to bring out details which it had been impossible to detect during years of work. He was enabled by this powerful instrument to carefully map the infra-red energy spectrum of the sun from wave-length 0.76 micron to wave-length 5.3 microns, revealing about 700 absorption lines and bands in this invisible region. These and subsidiary investigations were made public in the first volume of the Annals of the Smithsonian Astrophysical Observatory, published in 1900. He then directed his researches toward the solution of that fundamental question as to whether the emission of radiation by the sun is substantially constant in amount, or sufficiently variable to produce marked and predictable effects on the climate of the earth. This investigation had not, at the time of Mr. Langley's death, been completed, but it had proceeded so far as to indicate a very strong probability that the solar radiation outside the earth's atmosphere varies notably and frequently, in such a manner as to profoundly influence the temperature of the earth.

The inventiveness of mind displayed by Mr. Langley in all his work was remarkable. Among many devices which he originated are means for determining times of transit without personal equation; means for observing sudden phenomena, by substituting the observation of a place for a time; the bolometer and its automatic registering devices; and means for producing improved seeing by stirring the column of air traversed by a beam of light. He also re-invented, without knowledge of its earlier use, the principle of the coelostat, and employed that instrument about 1880 at Allegheny.

Mr. Langley often stated that even as a boy he was interested in watching the motions of hawks and buzzards, and he wondered by what mysterious power birds so much heavier than the air could maintain themselves in space and could move about at will without apparent movements of their wings. His dormant interest in the subject was aroused to action when, in 1886, he listened to a paper communicated to the American Association for the Advancement of Science. It seemed to him that prevailing theories as to how birds fly were not based on sound facts, and he resolved, as a fundamental problem, to

ascertain by scientific observation and experiment what mechanical power was required to sustain a weight in air and make it move at a given speed. It was at Allegheny Observatory, in 1887, that he was enabled to begin a series of observations in aerodynamics which extended over three years, and were aided in part by the Bache fund of the National Academy of Sciences. The results of this work were published by the Smithsonian Institution in 1891 under the title of "Experiments in Aerodynamics," and at once attracted the attention of physicists in America and Europe. The experiments were made upon plane surfaces and related to the long-disputed questions of air resistances and reactions. They established a more reliable coefficient for rectangular pressures than that of Smeaton; believing the frictional drag to be negligible, he proved that air pressures were normal to the surface; he disproved the "Newtonian law" that the normal pressure varies as the square of the angle of incidence on inclined planes; and showed that the Duchemin formula proposed in 1836 is approximately correct, and that the position of the center of pressure varies with the angle of inclination and follows approximately Joessel's law. He corroborated the work of Wenham who proved, in his celebrated paper of 1866,[a] that oblong planes are more efficient when presented with their longest dimension at right angles to the line of motion; and that planes may be superposed without loss of power if spaced at distances properly proportioned to the speed. The conclusion was also reached, usually known as "Langley's law," that "if in such aerial motion, there be given a plane of fixed size and weight, inclined at such an angle, and moved forward at such a speed, that it shall be sustained in horizontal flight, then the more rapid the motion is, the *less* will be the power required to support and advance it."

As a result of his observations, Mr. Langley announced in 1891 that it was possible to construct machines which would give such a velocity to inclined surfaces that bodies indefinitely heavier than the air could be sustained upon it and moved through it with great velocity. It was stated in particular that

[a] First Ann. Rept. Aeronaut. Soc. Great Britain for 1866, pp 28 and 36.

a plane surface in the form of a parallelogram of 76.2 cm. by 12.2 cm. (30 by 4.8 inches), weighing 500 grams (1.1 pounds), could be driven through the air with a velocity of 20 meters (65.6 feet) per second in absolutely horizontal flight, with an expenditure of 1/200 horsepower; or, in other terms, that 1 horsepower would propel and sustain in horizontal flight, at such a velocity (that is, about 45 miles an hour), a little over 200 pounds weight of such surface, where the specific gravity of the plane was a matter of secondary importance, the support being derived from the elasticity and inertia of the air through which the body is made to run.

In 1893 he published his paper on "The Internal Work of the Wind," in which he showed that the irregularities of the wind were much greater than had been supposed. He concluded that these irregularities might be a source of power and might to a considerable degree account for the ability of certain birds to soar with outstretched, unflapping wings. This paper, like the one on aerodynamics, attracted much attention and was published in both England and France The term "internal work" was here applied to pulsations of sensible magnitude always existing in the wind and having extraordinary possible mechanical importance. Mr. Langley[a] asserted his belief that as "a ship is able to go against a head-wind by the force of that wind, owing to the fact that it is partly immersed in the water, which reacts on the keel, * * * it is not impossible that a heavy and inert body, *wholly* immersed in the air, can be made to do this." He further said that he believed that the future aerodrome would utilize not only the particular pulsation of the wind described in the memoir, but also the ascending, lateral, and whirling motions of the wind.

Having become convinced that mechanical flight was scientifically feasible, Mr. Langley then began the construction of several model flying machines. Experimenting first with numerous small rubber-driven models of various designs, he built, from 1891 to 1895, four model aerodromes, one of them driven by carbonic acid gas and three by steam-engines. On

[a] The internal work of the wind. Smithsonian Contributions to Knowledge, vol. 27, 1893, p. 6.

May 6, 1896, his faith and perseverance were rewarded by the successful flight of his aerodrome No. 5 for a distance of 3,000 feet. The total flying weight of this machine was 26 pounds and the total area of support was 68 square feet. It was of the general type now classed as monoplanes, though with two pairs of wings, one set forward and the other in the rear of the two propellers. Never in the history of the world previous to that experiment had any such mechanism, however actuated, sustained itself in the air for more than a few seconds. Mr Langley was thus the first to produce successful flights, of convincing lengths, of models with an artificial motor, and thus paved the way for others who have achieved success with man-carrying flying machines

In 1898 Mr Langley, assisted by the United States Government, began the construction of a man-carrying aerodrome for purposes of further experimentation. When completed, in 1903, this machine weighed, with the aeronaut, 830 pounds, and its sustaining surface was 1,040 square feet. The gasoline motor of 52-brake horsepower, weighed, with cooling water, carburetter, battery, etc., somewhat less than five pounds to the horsepower. Defects in the launching apparatus resulted in such serious injuries to the machine that further experiments were suspended in December, 1903. "The machine," said Mr. Langley, "never had a chance to fly at all, but the failure occurred in the launching ways." It is interesting to note, however, that experiments with the Langley type of aerodrome did not actually cease in December, 1903, when Mr. Langley made his last trial, but as recently as August 6, 1907, a French aviator made a flight of nearly 500 feet with an aerodrome of essentially the same design.

The words of Professor Langley after the close of his experiments in 1896 were prophetic of what is now so rapidly coming to pass. He said:

> I have brought to a close the portion of the work which seemed to be specially mine—the demonstration of the practicability of mechanical flight—and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others. The world, indeed, will be supine if it do not realize that a new possibility has come to it, and that the great universal highway overhead is now soon to be opened.

On January 12, 1887, Mr. Langley was appointed assistant secretary of the Smithsonian Institution. On August 19th of that year Professor Baird died and on November 18th the board of regents elected Mr. Langley to succeed him as secretary, and for eighteen years he evidenced his ability as an administrative officer in a marked degree. To his efforts is due the foundation of the National Zoological Park at Washington "for the instruction and recreation of the people." To him, also, is due the establishment of the Astrophysical Observatory of the Smithsonian Institution, and it was during his administration that was begun the spacious new structure for the National Museum. During his administration, the permanent fund of the Institution was largely increased through the munificent gift of Thomas G. Hodgkins, part of the income of which, under the terms of the gift, has been devoted to the study of the earth's atmosphere in relation to the welfare of man.

Secretary Langley was a worthy successor to Secretaries Henry and Baird. All three were honored members of the National Academy of Sciences. Each won fame in his special field of study. Henry, the physicist, by his scientific researches in electricity, made discoveries which have been utilized in its application to the transmission of messages, to transportation, and to the generation of power for industrial work. He also inaugurated the system of daily meteorological observations, out of which grew the Weather Bureau; and, as head of the Lighthouse Board, he revolutionized the methods of lighthouse operation and signaling. Baird, the biologist, bent his energies to increase man's knowledge of animal life, and established the United States Commission of Fish and Fisheries, later known as the United States Bureau of Fisheries. Langley, the astronomer, will be long remembered by the world for his discoveries in astrophysics and in the science of aviation. Each of these men advanced the general activities and the prestige of the Smithsonian Institution, whose business affairs they administered.

Mr. Langley's published works, covering a wide range of topics, include nearly two hundred titles (several of them in French and German) and date from 1869, when he reported

on his solar-eclipse observations at Oakland, Kentucky, to 1905, when he contributed to the Astrophysical Journal an article "On the comparative luminosity and total radiation of the solar corona"

In addition to his researches in astrophysics and aeronautics, and his duties as secretary of the Smithsonian Institution, Mr. Langley was studiously devoted to general literature; was an exceptional French scholar, thoroughly familiar with the language, both spoken and written, and was particularly interested in the history of the French Revolution. His presidential address in 1888 before the American Association for the Advancement of Science evidenced his broad philosophic mind. In this address, discussing radiant energy, he said:

We have, perhaps, seen that the history of progress in this department of science is little else than a chapter in that larger history of human error which is still to be written * * * Shall we say that the knowledge of truth is not advancing? * * * It *is* advancing, and never so fast as today, but the steps of its advance are set on past errors.

Mr. Langley's ability as a scientific writer to express technical matter in words to be understood by all was well evinced by his book on "The New Astronomy," based on a course of lectures delivered before the Lowell Institute in Boston. The new astronomy relates to the physics of the heavenly bodies, their constitution, and not to their mere existence and position and other problems of the old astronomy. In the preface to this book he says:

I have written these pages, not for the professional reader, but with the hope of reaching a part of that educated public on whose support he is so often dependent for the means of extending the boundaries of knowledge.

It is not generally understood that among us not only the support of the Government, but with scarcely an exception every new private benefaction, is devoted to "the old astronomy," which is relatively munificently endowed already; while that which I have here called "the new," so fruitful in results of interest and importance, struggles almost unaided.

We are all glad to know that Urania, who was in the beginning but a poor Chaldean shepherdess, has long since become well to do, and dwells now in state. It is far less known than it should be that she has a younger sister now among us, bearing every mark of her celes-

tial birth, but all unendowed and portionless It is for the reader's interest in the latter that this book is a plea

The studies of metaphysicians and psychologists attracted his attention and he made a close study of the mysteries of psychical research. He had a passion for investigating the most abstruse, perplexing, and remote subjects of thought. These were to him in the nature of pastime and seemed to quicken his energy for his scientific work.

The achievements of Professor Langley were recognized by many universities and learned institutions. He received the degree of doctor of civil law from Oxford, doctor of science from Cambridge, and, among numerous others, the degree of doctor of laws from the universities of Harvard, Princeton, Michigan, and Wisconsin. He was awarded the Henry Draper Medal by the National Academy of Sciences, the Rumford Medal by the Royal Society of London, and the Rumford Medal by the American Academy of Arts and Sciences, as well as the Janssen Medal by the Institute of France, and the medal of the Astronomical Society of France. He was a foreign member of the Royal Society of London, a correspondent of the Institute of France, fellow of the Royal Astronomical Society of London, member of the Royal Institution of London, member of the Academia dei Lincei of Rome, of the National Academy of Sciences, and of many other well-known learned bodies.

Mr. Langley, although a member of very many scientific and other societies, was not a regular attendant at meetings and avoided holding office; perhaps the only exceptions were the presidency of the American Association for the Advancement of Science, the vice-presidency of the American Philosophical Society, and membership in the council of the National Academy of Sciences.

Mr. Langley's ancestors for more than two centuries were almost without exception of New England nativity and included many of the leading men of the seventeenth and eighteenth centuries. Without doubt it was through some of these forefathers that he inherited an indomitable perseverance, which obstacles and repeated failures could never daunt, and

likewise an originality of mind and breadth of view which were the principal characteristics of the man, leading him to eminent success in every endeavor

In concluding a touching tribute to the memory of Professor Langley, Dr Andrew D. White said of him:

Self-seeker he never was His labor, his thought, his efforts in every field, had as their one object the establishment of truth as truth For he had high aspirations and a deep faith—aspirations toward the best that humanity can receive, and faith in the truth that makes mankind free

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C. O. Whitman

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VII

BIOGRAPHICAL MEMOIR

OF

CHARLES OTIS WHITMAN

1842-1910

BY

EDWARD S. MORSE

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1912

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Of the biographical memoirs which are to be included in Volume VII, the following have been issued:

CHARLES OTIS WHITMAN.

BY EDWARD S. MORSE.

CHARLES OTIS WHITMAN was born in North Woodstock, Maine, December 14th, 1842, and died in Chicago, December 6th, 1910 The ancestors of Dr. Whitman, so far as the records in this country reveal, were sober, pious, and industrious people. An historian of the first four generations of the family says:[a]

> Posterity will seldom find occasion to blush upon looking back upon the past times of those from whom they have derived their origin Fortunate, indeed, may the generations now in being esteem themselves, if they can be sure to bequeath to their posterity an equal source of felicitation.

The first ancestor of the Whitman family in this country was John Whitman, who settled in the town of Weymouth, Massachusetts, about 1638. There is some obscurity as to the part of England he came from.

Associated with the industry and piety of the Whitman generations, there is indicated a strain of persistent obstinacy which crops out here and there in the genealogical records. If we may trust that horrifying Fox's Book of Martyrs, this strain is indicated early in their history. It is there recorded that one John Whitman left his family at Rye, England, in 1572, crossed over to Ostend "and there demeaning himself fanatically and offensively to Roman Catholics of that place was apprehended and consigned to the flames in which he perished without repining and in seeming exultation."

In this country, Nicholas Whitman of the third generation persisted in wearing his hat during church service long after this custom had been abandoned by the worshipers, and thus greatly scandalized the congregation.

[a] Memoir of John Whitman and his descendants, by Ezekiel Whitman; Portland, Maine, 1832.

In 1746 another member of the Whitman family came to an untimely death, at the age of 71, by insisting, against the pleadings of his associates, on driving an unruly team of oxen. The cart was upset and he was crushed to death.

From all that is known of Dr. Whitman's father he had a strain of unreasoning obstinacy in his fanatical adherence to the idea that the world was coming to an end at three o'clock P. M. (standard time?) on a certain date in 1843.

On his mother's side may perhaps be traced certain features of Dr. Whitman's character. His mother's brother, George F. Leonard, was a mathematician of rare ability as well as a good Latin and Greek scholar. He was principal of an academy in Norway, Maine, but finally lost his position through his fearless and outspoken manner. He made enemies continually by insisting that the other side was always wrong. He never yielded a point for expediency. After leaving Maine he settled in Newton Highlands, Massachusetts, and often lectured to laboring men in an attempt to improve their condition, and to direct them to avoid strikes and quarrels. His picture in the history of Woodstock, Maine, by William B. Lapham bears a resemblance to Horace Greeley. Mr. Leonard failed to become noteworthy on account of his ultra views on almost every question. He was a rank abolitionist too soon for popular esteem, a pronounced Universalist at a time when not to believe in a hell was considered sufficient reason for consigning one to that place.

These memoranda are given in the interest of heredity because one who was very intimate with Dr. Whitman said that he greatly resembled his Uncle Leonard in temperament, but had a much quieter mien and held his tongue.

As a young man Whitman was little given to talk, though he was a skillful debater. Dr. Whitman's father was a carriage builder by trade; in belief, a Second Adventist of the hardest kind. The son early became imbued with liberal ideas, and long and fierce were the religious discussions between father and son. His mother was a sweet, lovable woman esteemed by all, and from his mother's side it is believed that Whitman inherited all his gentler and dominant traits.

From Woodstock the family moved to Waterford, Maine,

and finally settled in Bryants Pond, Maine, in 1861. Here the father built a house, young Whitman aiding him in its construction.

The family consisted of two sons and two daughters, Whitman being the oldest. While not proud or distant, the members were in a way unapproachable No one seemed to know them very well and the neighbors never established any intimate relations with them. Diligent inquiries failed to show that Whitman was interested in the usual sports of boyhood. He showed no marked talent as a boy, except that he was very studious, very quiet in manner, and somewhat diffident He was slow in giving an opinion, but did so when urged. He never went into company or the usual country gatherings. In his school studies he showed marked aptitude for mathematics. He is remembered to have sung songs that were taught him, and it is said that all the Whitman family were good singers.

Mr. John M. Gould, a life-long friend of mine to whom I am indebted for all of these details, says:

> There is no hint from any of those I interviewed that young Whitman had any desire to play, draw, paint, climb mountains, travel, or build boat, engine or carriage, but though I have been in his old home and have interviewed his cousins and acquaintances, I am pretty sure they did not know much about the boy's life, thus showing that his tastes were different from the others and that he did not care to waste time on people not congenial to him.

Young Whitman became interested in birds at the age of twelve. He had a pet blue-jay which on its death he stuffed and mounted. This was his first attempt at taxidermy and in this difficult task he was self-taught. His interest in natural history was evidently spontaneous, for in his boyhood he was always interested in birds, squirrels, pigeons, etc. Later he showed exceptional skill as a taxidermist. His father's house was like a museum, as young Whitman not only collected birds, but had quite a collection of minerals. He was often seen working in his father's carriage shop, but only in making mounts for his birds or cabinets for his collections. In this way he learned the use of tools.

His father was poor and young Whitman began early to teach and for several terms was teacher of the school in

Bryants Pond. He also taught privately, receiving tuition from his pupils. In this way he earned the means to go to college. He was prepared for college by his Uncle Leonard at Norway Academy.

At the age of seventeen his hair turned white. He wore it long and brushed back. He always wore black clothes, was neat and clean in appearance, and was always polite, agreeable, and easy to get along with. As a teacher he was strict, just, impartial, and thorough, and was liked by all his pupils. He endeavored to teach his students to love those things which were right. Though greatly interested in birds, he never brought specimens to school or in any way alluded to them. He was scrupulous in attending to the prescribed studies and work of the school to the exclusion of other subjects. He never went to church and was regarded as an unbeliever and would have been called an agnostic in these days.

His commencement address at Bowdoin College was entitled "Free Inquiry" and, as Professor Lillie said in his biographical sketch of Whitman, was an early indication of an unfettered mind.

No one knew much about him except that he was always reading, studying, teaching, or collecting birds.

That he was inspired by the spirit that animated so many of his neighbors to enlist during the Civil War is attested by one who knew the family, who says that Whitman's father was opposed to the Civil War and would not allow his son to volunteer. Finally he was drafted and went before the examining board, insisting that he was sound and would go to the war. An examination, however, revealed some defect, probably due to some trouble of the eyes, and he was rejected. For the cause of science this was certainly fortunate.

As an illustration of young Whitman's patience and perseverance Rev. Harrison S. Whitman, a cousin, relates the following incident. He wanted a certain bird so much that he pulled off his shoes and stockings and waded into a pond and stayed there in the rain the best part of a forenoon waiting for the bird to come back and be shot.

He entered Bowdoin College as a sophomore in 1865 and

was graduated in 1868. He immediately took high rank, standing well in a class having fine scholars.[a]

He was out of college a good deal during his course, engaged in teaching to earn the means to continue his college work Shortly after graduating he gave a lecture in a church at Bryants Pond which was well received. The subject was of a philosophical nature as reported by one who listened to the lecture.

His room-mate, now Judge Clarence Hale of Portland, to whom I am also indebted for much information about Whitman, says:

> He kept our room full of mounted birds, and developed great fondness for natural history. Every week he made hunting trips covering a radius of ten miles about Brunswick. He had a fine genial disposition and no man in his class commanded more respect or was more generally liked. Although he had no boon companions or close personal cronies, we were always thoroughly good friends.

Judge Hale first met Whitman at Norway Academy in the spring of 1864. In the fall of that year, he taught in the high school at Turners Falls. When in college his appearance was odd and striking on account of his perfectly white hair, his neatness of dress, and courtesy of manner. He had the appearance of an idealist.

From 1868 to 1872 he was principal of the academy in Westford, Massachusetts.

As I recall Dr. Whitman, he was a man of medium height and weight. He always dressed simply and neatly and in summer wore light colored clothes. Three marked features in his appearance not only arrested one's attention, but remained indelibly fixed in one's memory. These were an abundance of the purest white hair crowning a rather pale and youngish face, large round nostrils, and blue eyes of unequaled depth

[a] Thomas J. Emery, Esq, a classmate of Whitman, says in a letter to me, "he did fairly well in his studies but did not take high rank. I don't think he was interested in any branch of science as such, but was very enthusiastic in the collection and preparation of specimens in entomology and ornithology, and my intimacy with him was largely the result of excursions I made with him with these objects in view."

and brilliancy. Eyes of a similar character I recall in only one other person and he, curiously enough, is also a distinguished naturalist and a member of this Academy. In manner Dr. Whitman was courteous and amiable, and in no way constrained or reserved; he had a quiet cultivated laugh and was agreeable in every way. He was hospitable and welcomed friends to his house and table in a genial and even in a bohemian spirit. In association and conversation with him, one could often see that his thoughts were on his studies.

My first acquaintance with Dr. Whitman began when, as an instructor at the Penikese school, he attended my lectures. He came fresh from the Boston English High School where he distinguished himself by his original methods in teaching certain branches of elementary science. He showed remarkable talent as an artistic draughtsman and his drawings under the microscope were fine and exact.

While at Penikese he studied, among other animals, a somewhat translucent ascidian known as *Perophora* I was also interested at odd moments in drawing the delicate microscopic details of this creature and upon comparing my drawings with his could easily see that his drawings were the better. As an instructor of the anatomy of the animal, he might have taken the platform and I the student's seat It was at this school that he seriously began his life work in science, for shortly afterwards he went to Dr. Dorhn's laboratory at Naples and then to Leipzig where, under the great Leuckart, he learned methods of microtome section cutting, staining of tissues, and processes of preparation far ahead of those used at Penikese; in short the modern methods of the embryologist and morphologist.

On the expiration of my engagement with the Imperial University in Japan, I was accorded the right of appointing my successor, and though my scientific friends included a number whom I should gladly have selected, I felt compelled to appoint Mr. Whitman as the one best fitted to conduct my class into modern methods of research, especially those of microscopic embryology and morphology. Though having no personal acquaintance with Mr. Whitman, aside from our limited association at the Penikese school, I knew of his ex-

perience as a teacher, realized his great ability as a microscopist, and was familiar with his skill as a draughtsman. In addition to these qualifications he was young, enthusiastic, and single. What better man could have been found to continue the work and grow up with the university?

The class that came under his tuition had been instructed in general zoology, comparative anatomy, classification, and the factors of natural selection. Members of the class had assisted me in dredging expeditions, extending from the west coast of Yezo, in the north, to Kagoshima Gulf in the south. As a general zoological museum had to be made for the university, collecting and museum technique formed part of the instruction. Mr Whitman came in and carried the class into methods of special research which were new to me and the older schools of naturalists. How well he did this work and the enthusiasm which he aroused in his students may be gathered by consulting the zoological memoirs published by the Imperial University, as well as certain morphological and microscopical journals published abroad.

One has only to recall the names of the lamented Mitsukuri and of Ijima, Yatsu, Ikada, Watase, Ishikawa, Sasaki, Oka, Miyoshi, Gota, Inaba, Hata, Tanaka, Kishinouye, Matsuda, Yamakawa, Hiroto, Harase, and many others to realize the triumphant success due to Whitman's work, and the general interest inspired.

Some of these students went to Europe and worked at the Naples station, others studied under Leuckart and Weismann. Nearly all of them are now instructors or professors and are doing sound scientific work for their country.

One of these students, Dr Watase, was for some years professor of cytology in the University of Chicago.

Dr. Whitman's rigid insistence on certain ideals while professor at the Imperial University led him into an attitude of antagonism toward the authorities. Not obtaining the conditions for his department which he insisted upon, and especially incensed by the refusal of the university to publish certain investigations of his students, except under the professor's name, the relations became strained and he left abruptly at the end of his two years' agreement. Coincident with his depart-

ure for home he printed a pamphlet of forty-four pages, entitled "Zoology in the University of Tokyo."

In subsequent years, he must have regretted some of the bitter expressions therein contained, for, could he have had the gift of prevision and seen the establishment of all the features he so strenuously insisted upon, his animadversions might never have been uttered. Obsessed by the importance and necessities of his own requests, he was unable to comprehend the attitude of the other side. Concessions must be made when habits of thought have been ingrained in a people for centuries.

In this very pamphlet he admitted the difficulty of establishing the latest appliances and other methods of modern research in certain laboratories of Europe and America How much more difficult it was for a nation, however civilized, which was just emerging from a state of feudalism, to promptly adopt the extreme modern methods of study when the importance of such work was incomprehensible to the higher officers of the university. This unfortunate experience, however, did not prejudice nor embitter him against the nation. He was always loyal in his appreciation of the people and exulted with the rest of us in the triumphs of Japan over China, and her later victories over Russia. He regarded with infinite pride the work done by his Japanese students. That the Japanese did not resent his sharp criticisms is an illustration of the sound and rational attitude of those to whom these criticisms were directed.

Dr. Whitman's memoirs are few in number, considering the high reputation he sustains among his colleagues, but those that he has published are models of what such work should be: clear, incisive, logical, and enlivened, at times, by flashes of sarcastic criticisms. His exquisite drawings were fitting accompaniments to these memoirs. His first memoir on the embryology of Clepsine, when he was thirty-six years old, was published in the Quarterly Journal of Microscopical Science, and was an inaugural dissertation to obtain the degree of Doctor of Philosophy at the University of Leipzig. Though he had been a student and an investigator for several years, he had published nothing before this time. It was not for want

of material that his writings were so comparatively few in number, for he has left in notes, manuscripts, and drawings a far greater amount of material than he ever published. This reserve was due to extreme caution and a desire to verify every point. As an illustration of his caution in this respect, I quote from one of his memoirs where, in describing the eye of the leech, he says:

> The main features of this eye had been known to me for two years, but it did not seem best to hasten the communication of the facts before giving the whole subject careful study.

Dr. Ishikawa, who studied under Weismann, in an article in a Japanese zoological magazine, says:

> When I was working in Weismann's laboratory I remember the name of Professor Whitman was often mentioned Once it was at the time when Dr Whitman had written about Bonnet's theory of evolution Professor Weismann said Whitman had not written much, but that his exquisiteness in investigation and his steadiness in thought might place him in the first rank of American zoologists

Professor Albert P. Mathews, in a tribute to Whitman in Science, says:

> His scientific work marks him a great master, for his finished published papers are truly masterpieces, both in content and expression

Had it not been for his scrupulous insistence upon accuracy we might have had a preliminary memoir on the great work he had been engaged upon for years, namely, the study covering the factors of evolution, mendelism, variation, heredity, etc, as developed in his study of pigeons. In all his memoirs, he followed the dictum of Louis Agassiz, who insisted that a student should make himself familiar with the literature of the subject before publishing.

Whitman quoted liberally from the works of other specialists in the subject under discussion. Reading these various memoirs of his, of which the first appeared, as has been said, in the Quarterly Journal of Microscopical Science, followed by another in the Zoologische Anzeiger, and subsequent ones in the Journal of Morphology, one becomes impressed with the keen analytical study and the insight revealed in the discussion of morphological problems.

His observations on the origin of the Trochosphere in Polygordius and its absence in other annelids, a feature which, despite the numerous studies on the subject, still remains a morphological puzzle, is a fine example of the logical methods which characterize his writings As an illustration of the character of his work and of the profound problems which he set himself to answer mention may be made of his work on the germ layers of Clepsine and the determination of the origin of certain organs from these layers, the seat of formative and generated energy, the relative influence of the nucleus and cytoplasm, and others of a similar character.

In these discussions, he reminds one of a German type of mind. In one of the biological lectures at Woods Hole entitled "Animal behavior" Dr. Whitman gave one of his most interesting and delightful essays. The table of contents even is as enjoyable as the menu of a rich feast. The lecture is crowded with facts which reveal his wonderful powers of observation. General considerations regarding the origin of instinct, which he shows precedes intelligence, and weak points in the habit theory, etc., indicate his thorough knowledge of the various discussions which have been published. In short, a fair presentation of this luminous lecture would be impossible in this brief memoir. It may stand as a model for discourses of this nature.

His bibliography embraces about sixty memoirs and communications, and while most of these were on embryological and morphological subjects dealing chiefly with the lower worms, he nevertheless made a number of communications on echinoderms, crustaceans, fishes, amphibians, and birds, and general zoology He rarely if ever wrote for the daily papers. When, however, he was called upon to write on subjects outside his special studies, he expressed himself clearly and to the point. In a short paper entitled "A broader culture for the doctorate," published in the University of Chicago magazine, he expressed himself in terse sentences many of which may be regarded as aphorisms, as in the following:

Research in its best sense is mental effort to grasp facts, interpret them, and express them in well chosen words. * * * Investigation is the normal thing for all living creatures, it is the trial and error

method all along the line from our Amœboid ancestors down to the full-fledged "Homo sapiens." * * * Annihilation is the part of those who miss the mark, survival the lot of those that achieve the best adaptation, and the highest type of adaptation is in brain organization. * * * Majority rule may do for politics, but it is minority intelligence that evolves the better ideas and sets the race ahead.

A complaint that I have often heard from professors of English composition in one of our great universities is recognized by Dr. Whitman in this short paper. He says:

So long as our high schools and colleges continue to send us pupils without a decent training in the English language and its fundamental sources; and so long as the capacity for thinking is dwarfed by the continual strain of cramming; so long as we tolerate a system of education contrived to surpress thought and to substitute therefor capacity only for memorizing, so long shall we have this lack of broad culture in our candidates for the doctorate.

Mr. Whitman's address when president of the Society of American Naturalists, which he entitled "Some of the functions and features of a biological station," is a masterly presentation of the subject, embracing as it does the results of his observations of zoological stations in Europe. This address abounds in short pithy sentences which convey suggestive truths. As examples we quote the following:

Ideas are absolutely essential, provided they are kept growing. Like all biological things, live ideas originate by germination and their growth is subject to no limit except in mental petrifaction. * * * Seeds may be kept for years without sensible change or loss of power to germinate, but it is because they are kept, not planted nor cultivated. Once planted, they must grow or rot; so it is with ideas.

One might profitably collect from this address and other addresses and reports by him a sufficient number of aphorisms and apothegms to form a daily calendar for the year. He believed, and sustained his belief with the strongest arguments, that a biological station should associate instruction with investigation, and insisted that the function of teaching aids in every way the specialist, and says:

I suppose no investigator, not even the most confirmed claustrophil, would deny that instruction compels thinking and improves ability to express ideas as well as to describe facts But wherein is the advantage with instruction? Every teaching investigator can answer that and the

answer will be, that power of exposition can be acquired and perfected by class-work and lectures in an extent otherwise unobtainable

His conceptions in regard to what a laboratory should be were certainly ideal. To him ideas were verities and had to be established. He planned conditions which, if carried out literally, would have required hundreds of thousands of dollars as a first endowment. That this is not an exaggerated statement may be judged by the concluding paragraph in his first annual report to the trustees of the laboratory. The most modest stipends for the number of investigators, teachers, attendants, and other assistants enumerated would easily require the sum of twenty thousand dollars, or four per cent on an endowment fund of half a million dollars! Now half the trustees that he appealed to had been struggling to raise funds for their own departments at the Boston Society of Natural History, the Harvard Medical School, and the Massachusetts Institute of Technology, and these men were rigidly impressed with the conviction that going in debt was not for a moment to be permitted by the authorities controlling their respective institutions. How could they be expected for a moment to permit any laxity of a similar nature in this new station for research and teaching. Furthermore they were greatly hampered in raising any considerable sum for the laboratory by the pressing demands of their own institutions. These reasons were responsible for the serious troubles which later came near to disrupting the institution at Woods Hole; and I say this with no reflections on Director Whitman, who poured out his own time and money lavishly for the work, but in justice to the distinguished naturalists who were on the board of trustees. Whitman was a genius, honorable and truth loving, but like many geniuses immune against the worry of financial responsibility.

Dr. Whitman's writings, whether scientific or popular, official reports, or reviews, indicate a mind crowded with ideas and stocked with knowledge. His metaphors show familiarity with many sciences. In discussing Bonnet's theory of evolution he was not content with Bonnet's final work, but made himself familiar with all that Bonnet had written upon the

question. Furthermore, he studied the works of contemporary and later writers on the subject. One is impressed with the evidences of wide reading and study in every contribution he has made to science.

His various annual reports to the trustees of the biological laboratory are interesting as showing how deeply he had at heart the success of the institution and how large his vision was as to its future growth and maintenance. In reading these official reports one observes the many allusions to zoological subjects. The inception and development of the laboratory are expressed in embryological terms, and the nomenclature of evolution is used in describing the growth and diversified activities of the school.

He wrote very few popular articles or articles of a general nature. In a paper of this character in the American Naturalist entitled "Do flying fishes fly" he begins by saying:

> Of all modes of animal locomotion, none has excited more general attention than that of flying creatures, and this is none the less so now that many who believe in the ultimate success of the flying machine have discarded the balloon theory and come to regard nature's contrivances for flight as the true models of aerial locomotives.

And this was written nearly a third of a century ago.

Dr. Whitman was led by his studies to follow Weismann in believing that natural selection pure and simple is sufficient to account for the present condition of living forms.

Interesting accounts of Dr. Whitman were written by three of his special students, Iwakawa, Ishikawa, and Takahashi, and published by the Zoological Society of Japan. These were translated for Prof. Frank R. Lillie and to him I am indebted for a copy of this translation. Whitman's interest in mendelism, the theory of De Vries, and certain problems in evolution led him to undertake an extensive and long continued series of experiments in breeding and intercrossing various kinds of pigeons. At one time he had over one thousand pigeons from all parts of the world. He crossed many forms, studied their color markings, followed out the results of heredity, considering even their psychological peculiarities, and has left a vast amount of data which it is hoped may some day be published. The work of caring for all these birds caged in little boxes

and transporting them back and forth from Chicago to Woods Hole was simply appalling. It required two freight cars to hold them. He expended thousands of dollars out of his own resources in these investigations and finally came to an untimely death by undertaking during a cold snap to place his precious birds in winter quarters. Professor Lillie says that in his zeal for his pigeons he forgot himself. He contracted pneumonia and died within a few days.

Burdened as he was with his professional duties at the University of Chicago and the directorship of the biological laboratory at Woods Hole with its multiform and distracting duties one stands amazed at the working capacity of the man. From Doctor Takahashi, who was a student and assistant under him at Chicago, I quote the following paragraph from a translation:

> As the result of long continued investigation, Dr Whitman's attitude toward evolution was selectionist, and he severely opposed the mutation theory of De Vries. He considered that variation occurred in nature in various ways and that nature selected certain ones among various ones

The expressions of Dr. Whitman are reported by Professor Ishikawa as follows:

> I cannot believe the mutation theory of De Vries; the cause that makes the species vary is selection. Nothing but selection can explain the cause of variation It is Professor Weismann who completely beat the mutation theory. It is Professor Weismann who completely confirmed that the selection theory is true. Weismann is certainly one of the greatest zoologists of the present day.

Allowing for indefiniteness of reporting and difficulties of translation, one can easily comprehend the spirit of the above. Dr. Takahashi goes on to say:

> Although Dr. Whitman might not stand absolutely against mendelism as yet, at least he suspected the theory and told me that an investigation of the varieties and hybrids of pigeons seemed to show that the mendelian theory did not contain much truth. At any event, when I was in Chicago, members of the biology department of the University of Chicago were all interested in a test of mendelism, and the leader in the investigations was Professor Whitman. There might, perhaps, be some mistake in Whitman's opinion of mendelism. No matter how it be, I have no doubt that his methods of accumulating facts and data were exquisite and impartial. If this wide-scoped investigation of his should ever fail to be published on account of his death, it is actually a great

loss to biology, whether he is medelian or not, and this is the main reason why I mourn bitterly for his death.

I cannot resist interpolating here the question asked of those, especially Englishmen, who are always holding up the virtues of the Chinese in disparagement of the Japanese: Where among the four hundred million Chinese can one be found who ever showed the slightest interest in questions of this nature or any question regarding the behavior or the cause of phenomena?

Gentle and courteous as Dr. Whitman was in manner, his love of truth, his hatred of injustice, his detestation of misrepresentation led him to criticise sharply and in some cases to use language far from parliamentary. He would hardly temporize in calling a liar "an economizer of truth." He was just as prompt in calling attention to his own errors of judgment, as in his memoir on spermatophores of leeches as a means of hypodermic impregnation. Without mentioning names, I cannot forbear quoting a few of his critical and satirical expressions: "To discover what has already been discovered and to refute what has already been refuted is a double-headed offense, inexcusable if the result of ignorance, unpardonable if done deliberately." And again after showing errors of interpretation in tracing the derivation of the nervous system in the leech he says: "The invention of such a blunder is as preposterous as its commission is impossible." In another memoir on Hirudinea he closed some sharp reflections by saying: "Charity and necessity alike commend us in taking leave of such oracular wisdom." And when this same investigator in his preliminary memoir promised an extended monograph on the subject, Dr. Whitman says: "It is to be hoped that before that impending final monograph is launched, our author will have discovered the unregenerate source of his present afflatus." These severe and cutting remarks seem strange, coming from one so kindly in disposition, yet his abhorrence of all pretense, of careless work, and of what he often believed to be intentional misrepresentation rendered him helpless in finding words strong enough to express his feelings.

Dr. Whitman has left two monuments to his memory and

these are the Marine Biological Laboratory at Woods Hole, of which he was the first director, and the Journal of Morphology, which he founded. The one in vigorous growth and prosperity, the other ceasing at the end of the seventeenth volume after publishing nearly ten thousand pages and hundreds of plates. The Biological Laboratory is too well known to require further mention, though an account of its early struggles and the almost single-handed fight made by its director at a critical time in its history is another illustration of the indomitable tenacity of Dr. Whitman in insisting on his ideas. He never compromised.

It is sad to recall the heart-breaking failures he experienced in carrying out other ideas, one of which was never born: The biological farm which he hoped to establish in Chicago and afterwards endeavored to induce the trustees of the Woods Hole laboratory to undertake as an adjunct of the institution. Much thought and planning must have been given to it by Dr. Whitman and these plans are probably preserved among his papers. It is to be hoped that some wealthy friend of science may in the future endow this biological farm and that it shall bear the name of Whitman. The bi-products of such a farm might be made a source of income for its maintenance, though one can imagine how Dr. Whitman would have frowned on the idea.

It is impossible to realize the amount of work and worry Dr. Whitman must have endured in establishing and directing that great undertaking, the Journal of Morphology. Though having the able cooperation of Dr. Edward Phelps Allis, Jr., still the selection of papers, the preparation of his own memoirs for its pages, the proof reading, and the final struggles to maintain it must have caused him many weary days and nights. That these struggles must have begun early is shown by a letter from Dr. Whitman to me.[a]

[a] "I fully appreciate your kindness in offering to do so much for the Journal. I have thought over the matter and have decided to postpone such an appeal as you suggest until it has become absolutely unavoidable. I am afraid I should not have the good luck to find others who would, like yourself, be willing to sacrifice so much to aid the Journal. Your offer is a most pleasing evidence of your cordial interest in the matter, and I am thankful for it."

His introduction in the first number of the Journal is an excellent presentation of the reasons for establishing such a publication. The needs of it are convincingly pointed out and in his appeal he reminds us that Germany, France, England, Austria, Holland, Belgium, Italy, Sweden, Norway, and Switzerland have their morphological journals and that our country should at least support one. His confidence in its success was based on the fact that we had in this country a number of morphological laboratories and many workers in the field. He believed that one journal at least could be creditably maintained. Any one familiar with its numbers will testify that with its generous size, fine printing, superb plates, many in color, it was creditably maintained to its last page and plate.

Knowing nothing of its financial condition, though the editors must have often helped from their own resources, attention must be called to the generosity of its publishers, Ginn & Co. After continuing the publication of the Journal to the bitter end, the publishers, in a final circular announcing its discontinuance, say: "For many years the Journals have been sustained by us at a financial loss which of late has amounted to several thousand dollars annually." The morphologists have since revived this valuable publication which is now published by the Wistar Institute of Anatomy and Biology of Philadelphia. An extended memoir of Professor Whitman's work prefaced by a biological sketch by Prof. Frank R. Lillie is presented in the Journal of Morphology, volume 22, No. 4. A deep analytical study of his various contributions to science has been prepared by Professors Conklin, Mathews, Morgan, Moore, and Riddle, and to this important contribution reference must be made. The life history of Professor Whitman is admirably set forth, with records of his marriage, his family, and the various positions he filled, always with devotion to the duties he assumed. Accompanying this memoir an exhaustive bibliography is given, prepared by Prof. Alfred P. Mathews, to whom I am indebted for the privilege of using it in this memorial. From this memoir I have also compiled *seriatim* the various degrees, honors, positions, etc., held by him.

To the editors of the Journal of Morphology I am indebted

for the portrait of Professor Whitman which accompanies this memorial.

He was the recipient of the following degrees: Bowdoin College, A. M., 1868; Ph. D., 1871; Leipzig, Ph. D., 1878; and the University of Nebraska, LL. D, 1894.

He was a member of the National Academy of Sciences, the Linnean Society of London, the American Society of Naturalists, and the American Ornithological Union; and a fellow of the American Association for the Advancement of Science and the American Academy of Arts and Sciences.

During his active and varied life he occupied the following positions: Westford Academy, principal, 1868-1872; Boston English High School, sub-master, 1873-1875; Imperial University of Tokyo, professor of zoology, 1880-1881; Harvard University, assistant in zoology, 1883-1885; Allis Lake Laboratory, director, 1886-1889; Clark University, professor of zoology, 1889-1892; Marine Biological Laboratory, director, 1888-1908; University of Chicago, professor of zoology, 1892-1911.

He was editor of the Journal of Morphology, the Biological Bulletin, the Biological Lectures, and the Journal of Biology.

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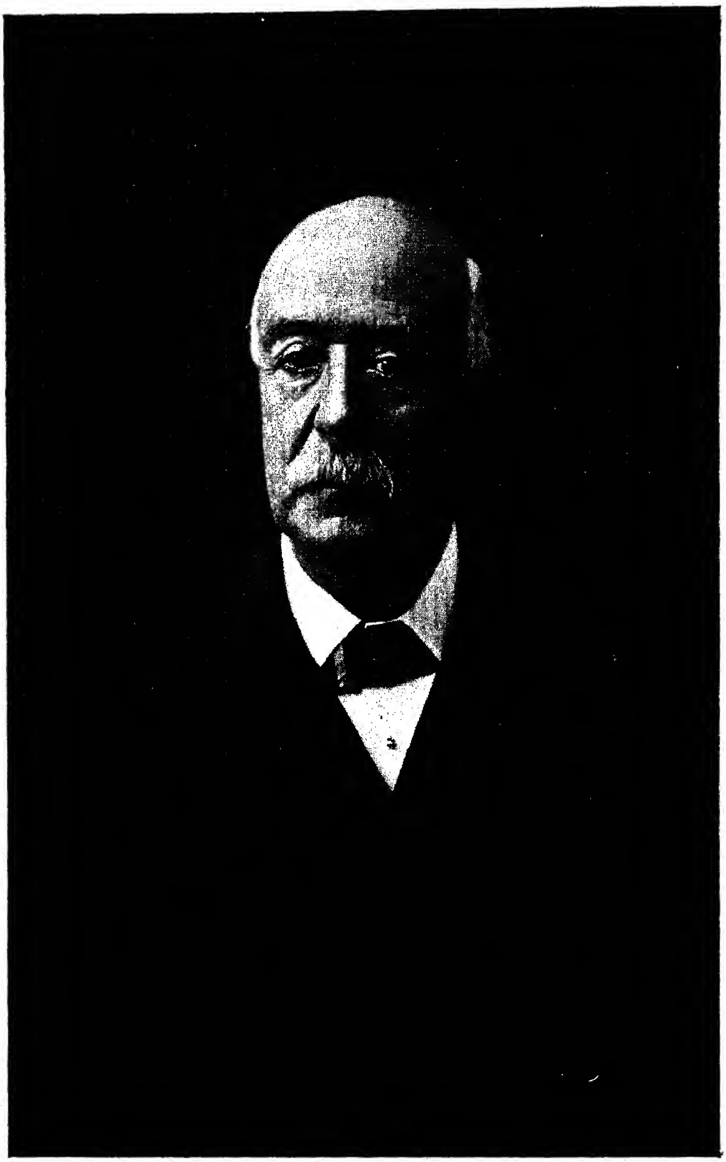

A. Agassiz

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BIOGRAPHICAL MEMOIR

OF

ALEXANDER AGASSIZ

1835-1910

BY

GEORGE LINCOLN GOODALE

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Of the biographical memoirs which are to be included in Volume VII, the following have been issued

ALEXANDER AGASSIZ.

BY GEORGE LINCOLN GOODALE.

An exhaustive memoir of Alexander Agassiz should consider his achievements in three distinct fields, namely, mining-engineering and administration, oceanographic research, and zoological investigation. His power of mental concentration and his economy of time enabled him to accomplish results which might fairly be regarded as full measure of activity for three men. To specialists in engineering, oceanography, and zoölogy must be entrusted the appreciation of the results attained; to one who has no claim to authority in any one of these fields of thought has been given the task of tracing in outline the principal dates in the career of Alexander Agassiz.

A large part of the energy of Agassiz was devoted for almost half a century to the enlargement of the Natural History Museum created by his father, and to the realization of his father's dream. The zoological section of this museum, known as the Museum of Comparative Zoölogy, was early placed in the hands of a small body of trustees, termed its faculty, and of this faculty Mr. Agassiz, after his father's decease, was always an active member. The present writer has had the privilege of membership in that faculty for nearly thirty years, and this affiliation brought him into intimate relations with its moving spirit. This unbroken intimacy constitutes the only apology which the writer can offer for having dared to accept the command from our president to prepare the present sketch.

Alexander Agassiz was born at Neuchâtel, Switzerland, December 17, 1835. His father, Louis Agassiz, was an instructor in the newly founded academy there, and had already secured a wide reputation as a naturalist. His mother, a sister of Prof. Alexander Braun, a distinguished botanist, possessed remarkable talent as an artist, and aided her husband greatly by the exact illustrations with which she enriched his scientific publications. The zeal for research and the artistic tempera-

ment which characterized father and mother descended to the son.

Alexander's early studies were conducted at Neuchâtel, a city where French is the spoken language. But as his mother was a German, he had at his services, from his earliest youth, the two languages, German as well as French. When he was eleven years old, he went to Freiburg in Baden, where he came into touch with his uncle, Alexander Braun, for whom he was named, and with Prof. K. Theo. v Siebold. In a private manuscript dated 1907, he says that it was from them that he "imbibed his first notions of natural history."

At the age of thirteen, after the death of his mother, he came to the United States to join his father, Louis Agassiz, who had accepted a professorship of zoölogy and geology in the Lawrence Scientific School, which had been recently established. At once he began his studies in the high school in Cambridge, and after two years of preparation entered Harvard College, graduating in arts in 1885, at the age of nineteen. Since his earliest years had been passed in French and German-speaking countries, he always found it a little difficult to pronounce certain English words, but his mastery in the construction of English sentences and his felicity in the choice of words were remarkable. When he wrote slowly his writings were models of clearness and precision.

After receiving his degree in arts, he carried on studies in the Lawrence Scientific School, and took a degree of bachelor of science, in engineering, in 1857. It should be mentioned in connection with this fact that he later pursued a course of studies in natural history in the same school, while he was assistant in the museum, and was given a second degree of bachelor of science, in 1862. The years 1858 and 1859 were in part devoted to teaching and to chemical work.

In 1859 he went to California as an aid in the United States Coast Survey, and passed a year in active service in the northwest. On his return to Cambridge, in 1860, he accepted a position as assistant in the Museum of Comparative Zoology, then just founded. In the same year he married Miss Anna Russell, a sister-in-law of Col. Theodore Lyman, his classmate in college and an associate in the museum.

Three years later he became interested in coal mining in Pennsylvania, but he still continued active work in zoology In 1865 he undertook the exploitation of an unprofitable copper mine in Michigan, in which he detected great possibilities. By uniting this mine with an adjoining one and by the application of improved methods of ore treatment, he placed the consolidated properties upon a productive basis. From this time on he had no further dread of the narrowness of means which had hitherto hampered him and his father; moreover, he could henceforth liberally aid his father in the furtherance of plans for the symmetrical expansion of the museum, and form for himself generous projects for exploration as well as for museum study. In spite of the too serious drafts made by the mining enterprise upon his time and strength, he did not at any time relinquish his interest in its management. He served successively as superintendent, treasurer, and president

In 1869 his health gave way under the protracted strain of the management of the mine in Michigan, and he was forced to suspend all work in connection with that undertaking With his wife and children he sailed for Europe in the autumn of that year, and his rest soon found him convalescent. With returning strength he journeyed to various points where he could examine collections of his favorite objects of study, and thus he spent his vacation in the most pleasurable scientific activity.

The titles of the scientific papers noted at the end of this sketch exhibit the wide range of his investigation and the steadfastness of his purpose. At this period he was devoting himself with singleness of aim to embryology and certain phases of systematic zoology. In this work and in his devotion to the museum, he must have given great satisfaction to his father, who always regarded him as his earliest student in the museum. His methods of study were largely those of his father, and his avoidance of the polemics of Darwinism at this time was an added gratification. This period is regarded by those best qualified to judge as the happiest and most productive of the years which he gave to zoölogy proper.

Toward the close of 1873 his father died. Before the end of the year his wife also passed away. The effect of this loss

upon a strong personality, endowed with a highly sensitive temperament, has been told in touching words by his intimate friend Sir John Murray It is enough for us to say that no change of scene or of work ever seemed to lessen the sense of that bereavement.

Even when a youth he had been much attracted to the study of the sea itself, and the distribution of its animals. In this study and in far journeying he now sought distraction from his loss. He began to give to exploration and oceanography a part of the time he had formerly devoted to embryology and systematic zoology.

His first expedition was to South America He explored certain portions of the coast regions of Chili and Peru, and gave special attention to Lake Titicaca. He charted the lake and determined its chief biological features, making collections illustrating its flora and fauna. He brought home also much archæological material. It is interesting to note that he gave a certain amount of attention to important geological aspects, especially to the question of land elevation.

In all of the numerous expeditions conducted after this date he continued his survey on a broad basis, neglecting nothing which might throw light on the relations of the lands explored

For each of his expeditions, ample preparations were made long beforehand with regard to arrival at ports of call, selection of favorable seasons, adequate provision of coal, and requisite appliances for deep-sea work. The whole course of each expedition was marked out accurately before he left Cambridge, and every precaution was taken to guard against misadventure. Hence he never met with any serious detentions. He was able to prosecute his work without interruption. In the exact records of these expeditions, the reader will find that the narrative itself is devoid of anything of a personal nature, and nowhere will be detected the fact that in a large part of each sea voyage, the leader of the survey was often completely prostrated by seasickness. His strength of will overcame all obstacles.

In his youth Agassiz made with his father, and later by himself, excursions along the Atlantic coast, and he early became familiar with the technique of dredging. In 1877, as

director of the scientific staff of the United States Coast Survey steamer "Blake" he became specially interested in oceanographic problems. In this steamer he made three cruises in the Gulf of Mexico, the Caribbean Sea, and along the lower east coast of the United States. In subsequent expeditions, he gave attention to the pelagic fauna of the Gulf Stream.

His voyages in the Pacific were made partly in the Fish Commissioner's steamer "Albatross," and in steamers chartered by himself. He left practically no important locality unvisited. The accounts which he gives of the coral and other islands examined by him, together with the results of his thalassographic researches, are embodied in illustrated quarto volumes and in the numbered publications of the museum which are noted in the bibliography accompanying this sketch. Many of the photographs reproduced in the numerous works were taken by his son Maximilian, who was his constant companion.

Mr. Agassiz passed the greater part of every winter in some climate milder than that of Cambridge, and he so planned his journeys as to make every month tell. In this manner he was able to accomplish an enormous amount of geographical examination without disappointment or disaster. On his return to the United States, after these long journeys, he would devote a certain amount of time to the mines in Michigan and then resume his zoölogical and other studies at the museum in Cambridge, but chiefly at the laboratory in Newport His friends in Cambridge, Boston, and Newport were not infrequently permitted to hear from Mr. Agassiz a preliminary and familiar account of his latest wanderings and achievements It is much to be regretted that none of these instructive untechnical reports of great accomplishments have been preserved. They possessed the charm which is associated with the remembrance of his father's lectures.

As has just been said, Mr. Agassiz conducted his laboratory studies based on the material gathered from his numerous expeditions, mainly at his home at Castle Hill, Newport. Near his residence he established in 1877 a sea-side laboratory well equipped with all requisite appliances. This laboratory was

indirectly an outcome of an experiment on the island of Penikese. Louis Agassiz, a year before his death, had been offered the use of this island, together with a certain sum of money, for the founding of a summer-school for instruction and research in marine zoology Alexander did not favor the acceptance of the offer, but he gave his loyal assistance, after the experiment had begun. Prof. Asa Gray rightly called the enterprise "the fatal gift of Penikese." Louis Agassiz was not at the time sufficiently strong to bear the additional burden of a doubtful experiment, and his death soon followed. But his son fully appreciated the desirability of having some place for research on the south shore, and he therefore established a laboratory near his home in Newport This laboratory was opened to instructors and students from Harvard and other colleges, under most charming and hospitable conditions, and remained active until 1897, when the neighboring waters were not wholly favorable for its further activity. Moreover, the establishment of a marine biological station at Woods Hole under the auspices of the Fish Commission rendered the maintaining of a public laboratory unnecessary.

Mr. Agassiz had also a home in Cambridge This was presided over by his father's second wife, Elizabeth Carey Agassiz, a lady of gracious presence and wide accomplishments. Her active interest in all things pertaining to the life of her husband and step-son was shown by her earnest work in conducting a school for young women, in order to add to the slender means of the family, in the early days. Her interest in the museum never slackened. She herself was an enthusiastic student of natural history, particularly on the instructional side, and, at a period when good handbooks were uncommon, assisted Alexander in preparing a useful treatise, known as Sea-Side Studies, a work which passed through two editions. Every move in every expedition, from the moment when Mr. Agassiz left Cambridge until his return, was watched by her with intelligent interest.

The Museum of Comparative Zoölogy, to which frequent reference has been made in this sketch, was founded by Louis Agassiz upon a plan which is not at all adequately described by its name. What he had in mind, as indicated by hints in

his reports and other communications, was a museum for research and illustration in all departments of what was then called natural history. It was intended to comprise everything from minerals, through the kingdom of plants, to the highest animals. It was to include also man regarded from an archæological and ethnological point of view. The first section of this comprehensive museum was erected in 1859

The staff at the outset consisted of a curator, Louis Agassiz, and numerous assistants, each in charge of a department of zoological investigation.

In the capacity of assistant, Alexander Agassiz served until 1875, when he was made curator. A second section of the museum, devoted to zoology, was added to the structure in 1871-1872. In 1876, the section known as the Peabody Museum of American Archæology and Ethnology, was erected at the southeast corner of the great quadrangle, where its apparent isolation gave little hint of the comprehensive plan which makes it an integral part of the whole edifice

By the close of 1882, the building had been extended to the extreme northwest corner. Practically all of these additions were made from gifts by Mr. Agassiz In 1888 and 1889, further extensions were made to accommodate mineralogy and a part of the botany, and to provide more room for zoölogy. At this period another section was also added to the Peabody Museum. It was largely through the active influence and the direct gifts of Mr. Agassiz that these additional sections were constructed. The façade fronting on Oxford Street still lacked an important element, namely, the southwest corner. In 1901-1902, this was filled by the commodious sections devoted to geology, the gifts of Mr. Agassiz and his two sisters, Mrs. Shaw and Mrs. Higginson In other words, the children had effectively carried out their father's original plan, and the great museum is now approaching completion. During this whole period Mr. Agassiz served the museum as an officer: 23 years as curator, 10 as director of the Museum of Comparative Zoölogy, and from 1902, until his death, as director of the University Museum, comprising all the sections. His gifts to the museum and to other departments of Harvard University considerably exceeded a million dollars.

It might naturally be thought that so busy a man, and one who had devoted to much of his time, energy, and means to the museum of the university, might fairly be excused from any further demands by the university itself. But his services were sought and freely given as overseer and as fellow of the corporation.

Mr Agassiz took a deep interest in the scientific societies which have their headquarters within reach of the museum, and for one of them, the American Academy of Arts and Sciences, he has made by his will a liberal allowance for a permanent home

Of his fondness for the National Academy of Sciences there is no need that one should speak here All can appreciate what he has done for it and for its future development. There is hardly a scientific society which does not carry his name on its rolls. There is not one which does not value his contributions to science as among the most important in their libraries.

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S. F. Emmons.

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VII

BIOGRAPHICAL MEMOIR

OF

SAMUEL FRANKLIN EMMONS

1841-1911

BY

ARNOLD HAGUE

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1912

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Of the biographical memoirs which are to be included in Volume VII, the following have been issued:

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1913.

SAMUEL FRANKLIN EMMONS.[a]

Samuel Franklin Emmons was born in Boston, March 29, 1841, and died at his home in Washington, March 28, 1911, lacking only one day to complete his seventieth year. He was the fifth child and third son of Nathaniel Henry Emmons, for many years a prominent and highly respected merchant of Boston, engaged in the East India and China trade.

His earliest known ancestor on his father's side was Thomas Emmons, whose name appears on the records of the Island of Aquidneck as aiding to found the Rhode Island Colony and later the town of Newport, from 1638 to 1641. He was admitted to be an inhabitant of Boston on March 29, 1648, one hundred and ninety-three years to a day before the birth of his lineal descendant, the subject of this memoir. On his mother's side his oldest known ancestor in America was Nathaniel Wales, of Yorkshire, England, who came to Boston in 1635 in the ship "James," sailing from the port of Bristol. All his American ancestors resided in Boston or its immediate vicinity. On the paternal side his grandmother was Hannah Franklin; his great-grandfather, Samuel Franklin, for whom he was named, was a cousin of Benjamin Franklin. His mother, Elizabeth Wales, was a daughter of Thomas B. Wales, well known for his activities in public and commercial enterprises and the first president of the Boston and Providence Railroad, one of the oldest railways in New England.

In his boyhood Emmons attended the select private school, held in the basement of the old Park Street Church, and in his twelfth year became a pupil in the then recently established Dixwell Latin School, and, as he said at the time, this was an event in his life, as he went there with the avowed intention of fitting for Harvard. Mr. Dixwell had the well-deserved reputation of being a gentleman of broad culture, of refined manners, and admirably qualified to prepare young men for college. Before opening his private school he had

[a] This memoir is revised and enlarged from a biographical sketch of Mr. Emmons, prepared by the writer for the Geological Society of America.

filled the position of principal of the celebrated Public Latin School of Boston. In addition to the prescribed courses to meet the requirements of college examinations, special attention was given to English composition, for which Mr. Emmons never ceased to be grateful. As he was well advanced in all preparatory studies, and in some of them belonged to the class that entered college a year in advance of his associates in school, he was given permission during his last year to take a special course in physical geography, a study which appealed to him; but what gave him particular pleasure was the construction of maps from memory without aid of instruments or field notes. It was an excellent training, both in the powers of observation and freehand topographical drawing. In later years, while engaged in exploration work in the Far West without maps, he realized that these boyhood studies stood him in good service. Every member of the class at the Dixwell School passed the final examinations without a condition. Many years later in life Mr. Emmons wrote: "I look back on Mr. Dixwell as the best teacher it was my lot to come in contact with. He had the power of inspiring his boys to love study for its own sake."

Emmons entered Harvard College in his seventeenth year and was graduated in 1861 with the degree of A. B. His class upon graduation numbered eighty-two, and though small even for that time, furnished its full quota of men who later occupied influential positions in the world and did their life work well, who were an honor to their university and to their classmates. Among them stood Samuel Franklin Emmons.

It is well worthy of note here that of the small number of those from the Dixwell Latin School who matriculated at Harvard, three of them later in life achieved wide reputation in the scientific world and were elected to membership in the National Academy of Sciences—Samuel Franklin Emmons, Henry P. Bowditch, and Charles S. Sargent. Bowditch and Emmons, lifelong friends from boyhood, served together as members of the Council of the Academy. They passed away within a fortnight of each other, and a few weeks before they would have taken part together in the semi-centennial anniversary of their graduation from Harvard. Justice Oliver Wen-

dell Holmes, of the United States Supreme Court, was also a classmate both in school and college.

Hon. Frank W. Hackett, formerly Assistant Secretary of the Navy, a college classmate, writes: "Emmons deserved praise for the fidelity with which he applied himself to his studies. He could always be depended upon as a man who was thoroughly prepared. His constancy in this respect won our admiration and esteem. I think he may be set down as one of the most diligent students of the class. In a word, it may be said that in his college course he was, with scrupulous care, laying the solid foundation of success in what turned out to be his happily chosen profession." All through his undergraduate career Emmons was active in college affairs relating to student life. He was fond of most athletic sports and took part in wrestling matches. His favorite recreation was rowing, in which he became proficient before entering college. He was a member of the Freshman crew.

Up to the time of entering college he had taken little interest in public or national affairs. Under the guidance of his classmate and warm friend, Wendell P. Garrison, later widely known as the literary editor of "The Nation," he began a course of reading on the issues involved in the slavery question. Among books which interested him was Helper's "Impending Crisis." Emmons joined the Sophomore Debating Society, known as the "Institute of 1770." Years afterward he said: "I got so interested in the national questions at issue in those days that I temporarily lost my painful self-consciousness and eagerly assumed the anti-slavery side in the debate, though it was unpopular among most of my classmates with whom I was intimate."

It is not out of place to recall here an incident in his college life. In the autumn of 1860 the Prince of Wales (Edward VII) traveled in America, and while in Boston visited Harvard. He was received on the campus with all college honors by the students. Each class turned out in full force with its own organization, but all under the direction of a chief marshal chosen from the senior class. During the reception the Prince expressed a desire to visit an apartment and see how the students lived. The Prince and his suite were taken to rooms

in Holworthy Hall occupied by Mr. Emmons and his cousin and classmate, Joseph Wales, greatly to the surprise of a company of young people gathered to witness the reception on the college green. In commemoration of his visit the room-mates hung a lithograph of the Prince on their walls, and upon graduation passed it on to the incoming occupants of the apartments. In 1886 Mr. Emmons, returning to Harvard on the twenty-fifth anniversary of graduation, found the likeness still on the walls, with the names of all those who had lived there since his time written on the back of the frame.

The seniors of 1861 had an experience which has fallen to the lot of no other class. The stirring events preceding the breaking out of the Civil War, followed by the election of Abraham Lincoln, created a profound interest in political and national affairs in the daily life of the students. Several of the class, including Emmons, organized a drilling club for military purposes, receiving instruction in Boston. The firing on the flag at Fort Sumter, April 12, and the subsequent attack of a mob in the streets of Baltimore on the Sixth Massachusetts Regiment on its way to aid in the defense of Washington aroused intense patriotic feeling. Intercollegiate sports, including the Yale-Harvard boat race, were abandoned, much to Emmons' disappointment, as he had given much time to his favorite exercise—rowing—and he had every expectation of handling stroke oar in the coming university race in June.

Events changed many matured plans. Several of the class, under special authorization of the faculty, were allowed to enlist in the army before graduation. Later many others volunteered, and no less than ten lost their lives in early manhood in the service of the Government. From purely patriotic motives Emmons earnestly desired to go to the war, but reluctantly yielded to the expressed wish of his parents, who were averse to his enlistment. A long-cherished ambition of the elder Emmons was that at least one of his sons should pursue a professional career. As Frank from boyhood had always shown the habits of a student, and was then completing a collegiate course, the choice naturally fell upon him, and as his own tastes led him to prefer an out-of-door life he began early to look forward to some form of engineering as a profession, although at that time he held no definite plans in mind. He

had suggested to his father that upon leaving college he should go to Europe for a three-years' course of study, but the parent at that time could not bring himself to agree to so long an absence.

In the spring of 1861, owing to the ill health of his mother, the family physician recommended for her restoration a summer trip to Europe. Probably because he was at that time the most available person to accompany her, and possibly because it took him out of the country during the early months of a disastrous civil strife, he was selected by the family to take his mother abroad. After passing creditably his final examinations, a few days previous to the closing exercises of the college, he sailed in June, on a Cunard steamer, out of Boston harbor for England, with his mother and a younger brother, who was nine years of age.

During the summer they made an extended journey, traveling as far as Switzerland, a country Emmons thoroughly enjoyed, having read with youthful enthusiasm while in college Tyndall's semi-scientific descriptions of glaciers and mountaineering in the Alps. Emmons himself did some good mountain climbing upon peaks which were at that time nearly untrodden ground. November found them in England, where he bade good-bye to mother and brother, who sailed for home. Emmons wrote: "Except for occasional blue spells that I was not with my classmates fighting for the preservation of the Union, my summer in Europe was an unending delight to me." Lingering for a while in London, December saw him again in Paris, bent upon some line of scientific work, but still undetermined in his own mind just where and what course to pursue.

It was his good fortune shortly after reaching Paris to make the acquaintance of the late Eckley B. Coxe, of Philadelphia, who was then a student at the École Impériale des Mines. It was an acquaintance which soon ripened into friendship lasting till the death of Coxe in the early days of a successful professional career. Emmons always regarded this meeting with Coxe as a turning point in his own life, and, acting upon the advice of his friend, he decided to prepare for the École des Mines. He found his college French totally inadequate for his purpose and his equipment for passing the required entrance examinations far from satisfactory. Settling down in the

Latin quarter among the students in the following February, he worked assiduously for nine months under private tutors, among other things going over the entire field of mathematics from arithmetic to differential calculus, without the use of text books, depending wholly upon verbal demonstration. In after life he alluded to this instruction as a masterly and brilliant course compared to anything in his previous student life. By good luck he was able to enter as a private pupil the chemical laboratory of the celebrated Prof. Adolf Wurtz, where he became sufficiently grounded in both chemistry and physics to enable him later to follow advanced studies in his scientific course.

In the autumn he entered the École des Mines as one of the few students enrolled in the class known as Éleves Externes, a privilege in those days granted only upon application of the foreign representatives of friendly governments, a privilege Emmons obtained through the courtesy of Hon. Wm. L. Dayton, the American Minister to France. Here Emmons worked industriously for two academic years, from November, 1862, to the summer of 1864. The faculty was regarded in Paris as an exceptionally brilliant one, but the two men who inspired the American student with enthusiasm were Elie de Beaumont and Daubrée.

At the close of the school year Emmons concluded that it would be more to his advantage to spend the last year of study in Germany than to complete the course in Paris. Two considerations influenced him: the one was that the practical side of mining engineering was taught more in detail at Freiberg, and the proximity of the mines to the town rendered access to the works far more convenient. The other was a desire to learn something of the German school of geology. Leaving Paris, he entered the Bergakademie at Freiberg, Saxony, in the early summer of 1864, in time to take the practical course of underground work in the mines, and also to familiarize himself with the language before lectures began in October. He remained in Freiberg till midsummer of 1865.

From Heidelberg, where I had devoted most of my time to chemistry and mineralogy in Bunsen's laboratory, I reached Freiberg in the spring of 1865, meeting Frank Emmons for the first time. His greeting was very cordial, and he gave me

much kindly advice based on his longer experience in the Bergakademie, advice which I found most valuable. Although he intended to follow the profession of a mining engineer, he devoted relatively little time to mechanical engineering, while I was always ready to lay aside metallurgical studies for field geology. Together we took all the week-end excursions with dear old Bernhard von Cotta, visiting many parts of Saxony and studying petrology as laid down in that now antiquated text book, Cotta's "Die Gesteinlehre" (Zweite Auflage, 1862). Many an evening Emmons and I spent together over the map of Saxony, acquiring our initiative experience in geological cartography, which later stood us in good service. Both came to realize the influence of Cotta upon our future careers, as he gave us much of his time. In this way, during these few months of German student life, was formed a friendship, which always endured. Emmons left Freiberg in mid-summer and traveled through parts of Europe, visiting many of the important mining centers. He spent the winter in Italy, making Rome his headquarters, and returned to Boston in June, 1866, after an absence of five years.

I returned to my home in Boston in December, 1866. A few weeks later, while in New York, I was offered a position as assistant geologist on the Geological Exploration of the Fortieth Parallel by my former fellow-student at the Sheffield Scientific School of Yale, Mr. Clarence King. Mr. King was then passing the winter in Washington, endeavoring by his individual efforts, aided by influential members both in the Senate and House of Representatives, to obtain the necessary legislation for carrying out the purposes of the expedition. The authorization was enacted by Congress without the customary delays. At the suggestion of Mr. King the official direction of the expedition was placed under the Chief of Engineers, Gen. A. A. Humphreys, notwithstanding that field work was to be carried on entirely by a civilian service. Mr. King was placed in full charge of the work and authorized to draw up a plan for the organization of the expedition, which he immediately proceeded to do, and which received the official sanction of his chief. On my return to Boston I sought out my friend Emmons, told him of the offer I had received, and

my acceptance of the position. He replied: "That is just the kind of work that would suit me. I heartily congratulate you." Shortly afterward I brought King and Emmons together, with the result that Emmons accepted a position as volunteer assistant, and in the following winter received an official appointment as assistant geologist, much to the gratification of all members of the organization.

On May 1, 1867, several members of the scientific corps, including Emmons, sailed from New York for San Francisco by way of the Isthmus of Panama and the Pacific mail steamer, along the coast of Mexico and California, the trip occupying three weeks. At that time the only other available route was by Wells, Fargo & Company's overland stage—a tedious, not to say dangerous, journey. After a delay of several days in San Francisco, gathering information of various kinds, including geographical data along the proposed line of the Central Pacific Railway across Nevada and Utah, a camp was established at Sacramento for equipment purposes. A ride of a few days across the high Sierras and down its eastern slope brought the party, early in August, to its first working camp on Truckee River, not many miles from the now flourishing town of Reno.

This ride over the Sierras followed a traveled route, but its physical and geological features were little understood. It was a glorious ride, the highway to the desert. All the party enjoyed it, but no one more than Emmons, who was full of youthful spirits and manly exhilaration over the work before us.

The first headquarter camp was pitched on what was then the western edge of the great American sage-brush desert, sparsely inhabited by a few frontier settlers expecting to become rich when the railway came along. There were practically no serviceable maps, and but slight knowledge of the country by those who lived in it except along the line of the overland stage route.

The first exploration work began along the California State line in the region of Pyramid and Winnemucca lakes. Some idea of the unsettled condition of things may be gathered from the fact that the party was frequently dependent upon information obtained from friendly Pah-Ute Indians. Much time was consumed in searching for water away from such streams

as the Truckee, Humboldt, and Carson rivers. Today it may seem difficult to realize that it was deemed essential by the War Department to provide a cavalry escort of twenty-five men to guard life and property. Not infrequently a mounted soldier accompanied a geologist when it was considered unsafe for any one to be quite alone on the mountains. Under such conditions the work from necessity took on more the nature of a reconnaissance than a survey.

The exploration as originally planned by Mr. King, modified by later experience and needs of the country, called for a survey of an area stretching from the Great Plains of Wyoming and Colorado over the Rocky Mountains, across the Salt Lake region and the desert valleys of Nevada, westward to the eastern boundary of California, determined by the 120th meridian from Greenwich. The proposed route of the first transcontinental railway was always included within the territory examined. This comprehensive plan called for a topographical map 100 miles in width, on a scale of 4 miles to the inch, based upon a system of primary and secondary triangulations, the elevations to be determined by a series of careful and frequent barometric readings, referred to a well-established main camp and checked by instrumental readings, by the railway from ocean level, across the Sierras, and thence along the Humboldt River. On these topographic maps geology was to be laid down. It should be borne in mind that such finished maps were seldom in the hands of the geologists till a year after completion of field work.

In addition to the corps of geologists and topographers, the party included an ornithologist, botanist, and, what was at that time an unheard of innovation, a skilled photographer. Under existing conditions, due in part to the large areas to cover in the limited time at our disposal and the lack of adequate funds to do the work commensurate with the standard of excellence desired, geology and topography were compelled to go hand in hand. Two well equipped organizations were constantly in the field during the summer and autumn, serving in quite separate areas, one known as the Emmons party, the other as the Hague party. Mr. King had his own camping outfit, dividing his time beween one or the other party, or else, as was usually the case,

conducting special investigations, such as the search for possible coal fields, and occasionally visiting areas outside the broad belt of exploration. Not infrequently both parties came together to talk over the complexities of geological problems. For instance, Emmons and I agreed regarding the front face of the Wasatch Mountains; King at first dissented from some of these conclusions, but was finally won over to our point of view. Again, Emmons and I disagreed on some structural problem connected with the Uinta Mountains. After much discussion King sided with Emmons, and the geology was represented on the maps in accordance with this decision. In this instance I declined to agree with them.

The short season of 1867 was devoted exclusively to western Nevada, in what was generally referred to as the Humboldt country, from the river of that name, whose principal tributaries had their sources on the Nevada plateau. The following year carried the survey across the remaining Great Basin ranges as far as the mountains bordering the western edge of Salt Lake Desert.

In 1869 the third season of field work was mainly confined to the desert ranges and the intervening arid valleys bordering the lake region, together with the imposing and strongly contrasted Wasatch Mountains. The year was signalized by the coming together of the Union Pacific and Central Pacific roads, one from the Missouri and the other from the Sacramento, the connecting rail with its silver spikes being laid just north of Great Salt Lake. In a sense it was an inspiration, as the practical reason for our work, as expressed in Congress, was to make known the natural resources of a country to be opened by a transcontinental railway communication. At all events it greatly facilitated the operations of the geological exploration. From the Wasatch eastward the belt of exploration traversed the elevated Mesozoic and Tertiary areas of Utah and Wyoming, crossed the relatively low divide separating the drainage of Green River from that of the North Platte, and, continuing eastward, included the Laramie plains, the northern extension of the Front Range, and the inclined slopes east of the mountains. It embraced a broad belt across the northern Cordillera. Mr. Emmons gave his attention mainly to geo-

logical problems connected with Green River Basin and to the Uinta Range and its dependencies. Field work was finally completed in the late autumn of 1872.

An illustration of Emmons' technical knowledge of the physical features of a country he had examined is well shown in the expedition undertaken by Clarence King in the autumn of 1872 to locate the recently reported new diamond field. The locality was kept a profound secret, although stock in the company was being liberally subscribed for in San Francisco. There was also good reason to question the genuineness of the discovery. In San Francisco it was the popular belief that the precious gems came from Arizona.

Mr. King was able to gather a few general facts about the supposed diamond field. He shrewdly suspected that the chosen locality was somewhere in western Wyoming, in an arid region south of the Union Pacific Railroad. The projectors of the swindle, who had visited the locality and carefully "salted" the ground with small diamonds and rubies, had left the railway at one station and returned to it at another still farther eastward. At that time, it will be remembered, there was but one transcontinental railway. These and a few additional facts induced Mr. King to search for the land of untold riches. Primarily he was impelled to seek the hidden treasures from the fact that he was unwilling to have such a source of wealth within the belt of exploration and know nothing of its occurrence and value. Equipping a small party, under the direct guidance of Mr. Emmons, the bogus diamond field was located on a small stream flowing into Vermilion Creek, a tributary of Green River. The precious gems were found sparsely scattered over the ground, presumably having been brought to the surface by the industrious ants, whose enormous heapings of fine gravel carried both diamonds and rubies. Mr. Emmons noted the fact that each diamond discovered was always associated with the same number of rubies. It was clearly evident to all members of the party that wherever a diamond was found the ground had been tampered with only a short time before. Clarence King returned to San Francisco. "The diamond swindle of 1872" was exposed and many thousands of dollars saved to the "get-rich-quick" investors. Mr. King, very properly, was highly

commended for his achievement. In the opinion of the writer, the success of the expedition was in great measure due to the expert knowledge and skill of Mr. Emmons.

An important investigation outside the belt of the Fortieth Parallel exploration, in which all the geologists were engaged, included visits to Mount Shasta, Mount Rainier, and Mount Hood, the primary object being a comparative study of the lavas of the volcanoes with the Tertiary igneous rocks of the Great Basin and incidentally also an examination of glacial phenomena. The latter proved to be both instructive and important. Active glaciers were found on all three mountains, being the first authentic discovery of typical glaciers within the United States.

Mr. Emmons climbed Mount Rainier, at that time a difficult ascent, the top having been reached only once before, and that earlier in the same summer Mr. King spent several weeks on Mount Shasta, while the writer ascended Mount Hood, studying its glacial system. Several years later Mr. Emmons delivered a popular address on "The Volcanoes of the United States Pacific Coast" before the American Geographical Society, which was published in the Journal of the Society.

The first winter (1867-1868) after the inauguration of the work on the Exploration of the Fortieth Parallel was spent in Virginia City, in a study of the Comstock Lode and the geology of Mount Davidson and the adjacent country, situated just south of the southern line of the area of exploration. In successive years winter quarters were established either in San Francisco, Washington, or New Haven. After the completion of field work the offices for the final preparation of the report, with its accompanying atlas, were located in New York. Here Mr. King and his two colleagues worked together and lived together in ties of closest friendship.

In the first volume of the report issued, but volume III of the published series, Mining Industry, will be found a chapter by Mr. Emmons on the "Geology of the Toyabe Range," accompanied by a map of those isolated mountains, which extend in a north and south direction for over 60 miles, and at that time already well known for their silver deposits. Austin, in the northern end of the range, the headquarters for mining activity

in that region, was then the most important town in central Nevada. The same volume contains a shorter but characteristic paper entitled "Geology of the Egan Cañon District." Both contributions are of interest as being his first scientific publications on mining geology. In his field work he endeavored to visit every locality where silver and lead ores were reported, yet it was characteristic of the man that he invariably began his examination of such localities by a study of their geological features before taking up the occurrence of any ore bodies.

Emmons' great work, so far as the exploration of the Fortieth Parallel is concerned, will be found in the report on the Descriptive Geology, volume II of its publications. The entire report is the work of the two assistant geologists. It was presented to Mr. King in January, 1877, and by him transmitted, the same month, to Gen. A. A Humphreys, Chief of Engineers, U. S. A., who was also one of the founders of this Academy. This volume, containing 890 pages, was printed by the close of the year and issued soon after. In it is a description of the country, treated geographically, beginning on the Great Plains and progressing westward across the widest part of the northern Cordillera. An endeavor is made to give the structural details and salient geological features lying between the meridian 104 degrees west and the meridian 120 degrees west, the latter being the eastern boundary of the State of California. The volume of atlas maps upon which the early geology was laid down, including the accompanying geological cross-sections, bears the imprint of 1876. A few advanced sheets, showing the geology of the Uinta Range, were distributed by Mr. King several months in advance of publication, as certain structural features were already a matter of discussion. Nearly all the great divisions of geological time are represented on the atlas sheets, and in volume II are described with more or less detail. In this volume the term Laramie formation is used in geological literature for the first time. The necessity for a formation name for a great series of beds covering many hundred square miles in area was readily recognized. The name was suggested by one of the authors of the volume and warmly indorsed by Mr. King, provided it would be acceptable to Dr. Hayden, who had, of course, observed the formation at a number of localities in

the Rocky Mountains. Dr. Hayden cordially agreed to the adoption of the term Laramie. During the last thirty years probably no geological horizon has been more discussed from many points of view, with all the accumulated evidence brought to bear upon the study of this series of beds.

Throughout all these years, in field and office, Emmons worked assiduously and with unfailing enthusiasm. Upon the completion of the Descriptive Geology, after ten years of service, Emmons resigned his position to give attention to personal matters. Among other things he engaged actively in cattle ranching, and for some time made his home in Cheyenne, Wyoming.

The act of Congress creating the Bureau of the Geological Survey and placing it under the Department of the Interior was approved March 3, 1879; three weeks later the President nominated Mr. Clarence King as its first director; on April 3 the Senate confirmed his nomination, and on May 24 Mr. King took the prescribed oath. By this legislation all existing surveys and exploring parties ceased to have congressional authorization.

It is not out of place to record here that the establishment of the Bureau of the Geological Survey was in large measure due to the action taken by the National Academy of Sciences in response to a request from Congress in the following clause: "The National Academy of Sciences is hereby required at their next meeting to take into consideration the methods and expenses of conducting all surveys of a scientific character under the War or Interior Departments and the surveys of the Land Office, and to report to Congress as soon thereafter as may be practicable a plan for surveying and mapping the Territories of the United States on such general system as will in their judgment secure the best results at the least possible cost, and also to recommend to Congress a suitable plan for the publication and distribution of the reports, maps, and documents, and other results of said survey." The matter was referred to a special committee, whose report, after its adoption by the Academy, was transmitted to Congress by its President. The organic act creating a Geological Survey as a Bureau of the Department of the Interior followed closely the methods and

suggestions proposed by the Academy. The great value of this legislation and its far-reaching consequences are now apparent to all interested in the scientific work of the Government.

One of Mr. King's first official acts was to secure the experienced services of Mr. Emmons, and on August 4 of that year appointed him geologist in charge of the Rocky Mountain division, with headquarters at Denver. The first two lines of his instructions read as follows: "You will devote the first years of your administration of your division exclusively to a study of the mineral wealth of the Rocky Mountains." In accordance with these instructions he was requested to prepare, without delay, a monograph on the Leadville mining region of Colorado. The Geological Survey having undertaken the collection of the statistics of the precious metals in connection with the Tenth Census, the work was placed in charge of Mr. Emmons and Dr. G. F. Becker, who were authorized to prepare the statistical schedules and to employ the necessary staff of assistants. The men whom they selected were for the most part mining engineers The results of the work were published in volume XIII of the series of Census reports. A feature of the volume is the publication of geological descriptions of the more important mining regions, and Mr. Emmons gives, for that time, an admirable chapter entitled "Geological Sketch of the Rocky Mountain Division," which can not be ignored by any one interested in the physical geology of Colorado.

Notwithstanding the time required for the Census volume, Emmons devoted the greater part of his personal attention and energy to the Leadville monograph. He brought to the task a well-trained mind and the exceptional experience of ten years on the Fortieth Parallel Survey; indeed, the monograph shows the influence of the earlier work and his method of thought. Nowhere is this more clearly shown than in his decision to acquaint himself with the geology of the Mosquito Range before taking up such intricate problems as the ore deposits undoubtedly presented. He felt he might be led into error or fail to grasp essential phenomena of ore deposition unless familiar with the structural features of the adjacent country. This mental attitude of Emmons has been well brought out by Whitman Cross, his field assistant and daily companion at Leadville.

Emmons conquered in a masterly way the details of the complex ore bodies, and he undertook to solve no problems until he assured himself that he knew his ground. Even as early as the autumn of 1880, in his report to the Director of the Survey, he presented many essential features of the region. An abstract of the monograph on the geology and mining industry of Leadville, accompanied by an admirable geological map, was published in the Second Annual Report of the Director, and served to meet the needs of the engineers working on the ground. The monograph itself, however, was held back for finishing touches and the results of chemical investigation, although the method of presentation and final conclusions remained essentially the same.

The monograph and atlas, containing 35 sheets of maps and sections, appeared in 1886 It attracted immediate attention not only of geologists and practical mine workers, but of all classes of scientific men. It won for its author an international reputation, being received both in America and Europe as a work of the highest order. Since its organization, probably no single publication of the Geological Survey has exerted a more beneficial influence and stimulated more discussion. It everywhere aroused investigation of the origin of ore deposits, and similar studies were prosecuted elsewhere throughout the northern Cordillera. The volume became a model for younger economic geologists. One thing which greatly aided the success of the monograph was the masterly, orderly way in which the author arrayed his facts, and the clear, concise English in which they were presented. After twenty years of active mining operations at Leadville and the exploitation in many directions of new ore bodies, Mr. Emmons, aided by Mr. John D. Irving, renewed his investigations, with the intention of bringing the earlier work up to date. Under the title of the "Downtown District of Leadville, Colorado," a few of the more salient features of this re-examination, with the light thrown by new discoveries, were issued as a bulletin of the Geological Survey in 1907, both names appearing as joint authors. The final publication of a revised monograph has been delayed, partly because of the failing health of Mr. Emmons and in part because the greatly increased development of mine workings has made

the construction of maps and sections far more laborious than was the case in the early days, when shafts and workings were comparatively few.

The sudden death of Mr. Emmons occurred before the monograph was finished. Fortunately, as the maps and sections by Mr. Irving were already well under way, it should be possible to publish them without much further delay. It is surprising to what extent Mr. Emmons' early interpretation of the structural features of the Leadville district have been borne out by the later developments, for only in the more complicated portions of the district, such as Breece Hill and East Fryer Hill, have any essential modification of his views been found necessary.

Mr. Irving tells me that Mr. Emmons left no finished manuscript stating his recent views with regard to the origin and genesis of the Leadville ores, so that we have no written record of the changes in his theories of ore deposition. He had, however, freely and often discussed the question of genesis with Mr. Irving in its many details. Mr. Irving writes me that "Mr. Emmons felt the influence of the recent tendency to ascribe the origin of the ores to the action of eruptive rocks. His original views as to the circulation of waters along contacts of limestone and porphyry suffered no modification, but he inclined to the belief that such waters were in part, if not wholly magmatic and not derived from surface or meteoric circulation."

During the following years of Emmons' active duties most of his important contributions to geological science were issued as official documents of the Geological Survey. As they are accessible to all, and the titles are found in the list of his scientific writings appended to the biographical sketch, it seems unnecessary to mention them all, considering the limited space available. They appear in one or another of the many forms of publications adopted by the Government Bureau. Several of them were published as descriptive texts accompanying folios of the Geologic Atlas. Many of these writings are of the highest value and bring out his power of presenting geological details in a lucid, simple style. In some of these he was the sole author, while in others he shared with his assistants

the preparation of the text. Among them may be mentioned a characteristic chapter on "The geology and mineral resources of the Elk Mountains," a rugged region in western Colorado, famous for the complexities of its structural problems and well known for its mineral wealth (Folio No. 9, 1894). Another area in Colorado, known as "The Ten-mile District," was described in detail and illustrated by a remarkable series of cross-sections. In this instance the explanatory text was written entirely by Mr Emmons (Folio No. 48, 1898). In "Economic Geology of the Butte District," which appeared in the Butte Special Folio (No. 38, 1897), the fissure system is divided into typical fissure veins and replacement veins, with a discussion of the distribution of ores and ore deposition. In the Tintic Special Folio (No. 65, 1900) Mr. Emmons publishes only general conclusions upon ore deposition based on an array of facts presented by the authors of the folio, George Otis Smith and George W. Tower. In a few paragraphs he treats of the manner of fissuring and both contact and cave deposits. He regards the caves as the result and not the cause of ore deposition. The above publications are careful investigations upon widely separated mining areas in Colorado, Montana, and Utah.

To the annual reports he contributed a number of articles, among them an exhaustive one entitled "Mines of Custer County, Colorado," which appeared in the seventeenth report, published in 1896. In the same year there was issued from the press the well known and elaborate monograph on the "Geology of the Denver Basin," a volume devoted to structural problems of the broad region of country lying east of the Front Range, a work in striking contrast to Mr. Emmons' more recent contributions in the line of economic geology. In this volume he is aided by his two principal assistants in Colorado, Mr. Whitman Cross and Mr. George H. Eldridge, who furnished a large part of the text. In the series of Professional Papers published by the Survey may be found articles from Mr. Emmons' pen, serving as introductions to the work of younger men, upon mining districts in the far West.

Notwithstanding the fact that administrative duties occupied so large a share of his time, Mr. Emmons was able to con-

tribute to scientific journals and societies on a wide range of geological subjects, including dynamic problems, orographic movements, and the many phases of the genesis of ore bodies. In this connection it is only necessary to mention his papers and discussions on Secondary Enrichment of Ore Deposits, which appeared from time to time in the Transactions of the American Institute of Mining Engineers.

Mr. Emmons' keen interest in the geological and structural features of mining areas outside of this country is shown in his paper on the "Geological Literature of the South African Republic," printed in the Journal of Geology. Within a few months of his death he published articles on the Cananea Mining of Sonora, Mexico, and the Cobalt District of Ontario, both of which he had personally carefully studied. His last paper, entitled "Criteria of downward sulphide enrichment," will be found in Economic Geology, volume 5, an article closely related to his earlier contributions on the secondary enrichment of ore deposits.

In strong contrast to these technical papers is his loyal and sympathetic tribute to his old and dear friend, Clarence King, in the biographical memoir read before the National Academy of Sciences.

As early as 1874 Mr. Emmons was made a fellow of the Geological Society of London, and at the time of his death was one of the oldest members in this country. Throughout this long period he always kept himself in touch with its publications, especially contributions which treated of the geology of unexplored parts of the world. He joined the American Institute of Mining Engineers in 1877, took an active part in its proceedings and discussions, and was elected three times as one of its vice-presidents. He was one of the founders of the Geological Society of America, and chosen its president in 1903, delivering, on retiring, a notable presidential address on "The Theories of Ore Deposition Historically Considered." At the time of his residence in Denver, while in charge of the geological work in Colorado for the United States Geological Survey, he aided in the organization of the Colorado Scientific Society, and was elected its first president in 1882. The society now ranks among the most active scientific bodies in this coun-

try. In 1892 he was elected to membership in the National Academy of Sciences He was also a member of the American Academy of Arts and Sciences, the American Philosophical Society, the Washington Academy of Sciences, and the Geological Society of Washington, of which he also served one term as president. He was an honorary member of the Société Helvétique des Sciences Naturelles. He received the honorary degree of Doctor of Sciences from his Alma Mater, Harvard University, and from Columbia University in 1909.

The fifth session of the Congrès Géologique Internationale met at Washington in the summer of 1871. Mr. Emmons ably filled the position of general secretary, which was in no sense a sinecure, requiring months of arduous work, as a large share of the responsibility for the success of the congress fell upon his shoulders The conditions for such meetings in this country were essentially different from those in such European capitals as London and Paris. Ever afterward he took an active interest in similar congresses, and, attending several of them as delegate from America, served as vice-president at St. Petersburg in 1897, Vienna in 1903, and Stockholm in 1910, taking part in many of the more important geological discussions specially organized for the different congresses.

During his whole life Mr. Emmons' personal appearance had distinction; tall, erect, and slender, his carriage was graceful and unstudied. In the early days of his out-of-door professional work he was extremely active and alert. While he may have had a certain enjoyment in the pursuit of large game, he always seemed to prefer a long-range shot, perhaps at a rabbit in the sage-brush or a grouse in the pine timber. It was the exactness and finish of the shot, rather than the bagging something, that he cared for. A good mountain climber, he disliked a long walk on level ground. While in Leadville he wrote to a friend: "I fear boyish exuberance has left me, but keen zest for field work is as strong as ever" The probable explanation of this attitude can be traced to the fact that memtal effort and physical exercise had to go together, and before long the sense of responsibility, which was always a strong characteristic, got the better of enjoyment of mere bodily exhilaration.

During the thirty years of his active service in the Geological Survey he gave to it a thoroughness and lofty devotion. If he demanded high standards of scientific work from those with whom he was associated, he afforded an example by maintaining them himself. While in charge of the division of economic geology he gave personal supervision to the investigations of others, and never wearied in aiding younger men, training them in methods of work, even advising them as to the form of recording their notes. He always sought to inspire them with love of research for its own sake. He often said, in the kindliest way, of young men fresh from the technical schools: "They have excellent powers of observation, but their English is wretched." They all loved Mr. Emmons and kept for him their appreciation and respect, and he cared very much for their affectionate regard. Under a somewhat indifferent manner he had a warm and tender nature. His closest friends, those of a lifetime, never knew him to be guilty of an unworthy action, and if he ever cherished a resentment it was not without good cause. He was always ready to discuss differences of opinion in a cool, dispassionate way, showing a desire to get at the truth rather than to carry his own point. He was charitable and modest, while preserving with proper dignity the high professional and personal position he had so honestly earned for himself. He was domestic in his tastes, but no recluse. His friends have the happiest remembrance of his refined hospitality, and his associates of the National Academy of Sciences can never forget his eagerness to enjoy the privilege of entertaining them during their annual meetings in Washington. He left a widow, but no children.

His later days were, it is to be feared, full of patient endurance of physical pain—it was patient endurance—but he worked all the time and was kindly and gentle always. The younger men of his profession may not always have realized how helpful he had been to them until he could help them no more. His oldest friends, with whom he had built up his character, as well as his professional standing, grieved for him most because they knew him best. There were many of these friends all over the world, but none were so close as the few with whom he worked as a young man.

While for a long time Mr. Emmons had been in failing health and his condition the cause of anxiety to all, the final end came as a surprise to family and friends. He passed away in peaceful, restful sleep during the early hours of the morning. He left a noble record of life's work well performed.

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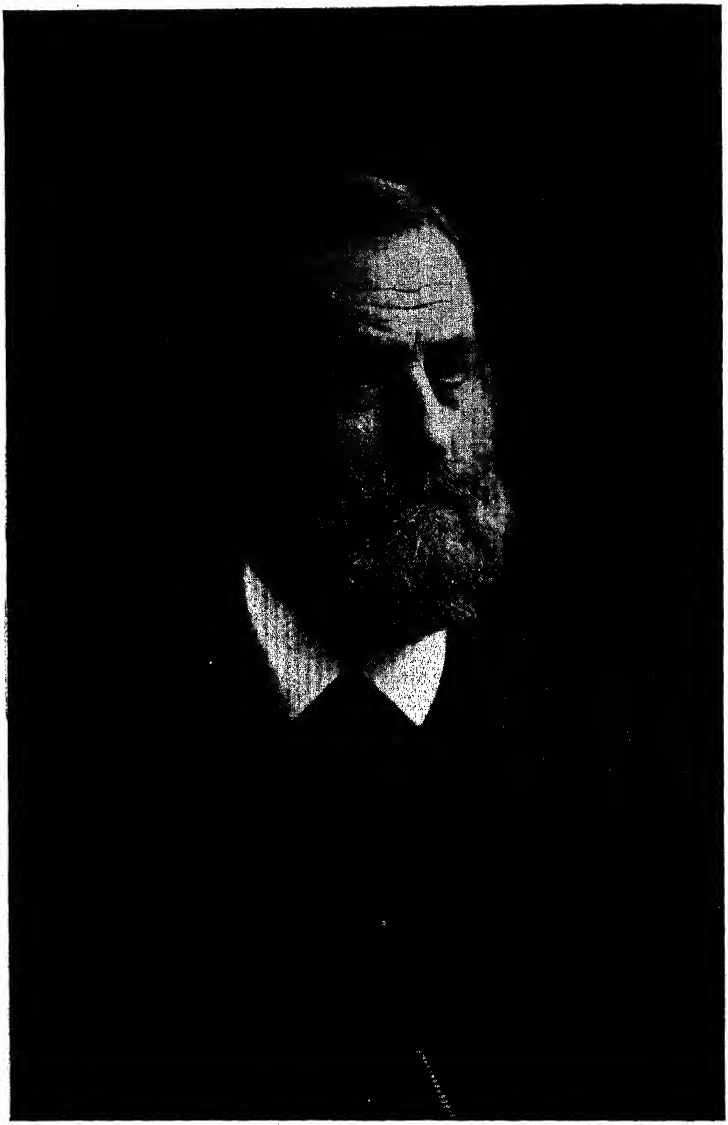

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Joseph Leidy

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JOSEPH LEIDY.

The name of Joseph Leidy will endure both as the founder of vertebrate palæontology in America and as the last great naturalist of the old, or eighteenth and early nineteenth century type. Among zoölogists he was the last to treat of the whole animal world from the protozoa to man, rendering in every branch contributions of permanent value. From his researches among the minerals, plants, infusorians, entozoa, and mollusks, he ranged into comparative anatomy as well as into his greatest field of research, vertebrate palæontology. In the year 1852 we find him writing upon fossils from the West, the geology of the Badlands, the life history of bees, their anatomy and the physiology of their reproductive organs, as well as entering the discussion of some new fungi with an English microscopist, the specific determination of various parasites, as well as numerous plants, the investigation of some new points in comparative anatomy, the observation of the movements of some new Rhizopods His encyclopædic knowledge, broad grasp of the whole field of natural history, precision and originality of observation in every field, present a combination of endowments which will never reappear in a single individual.

In vertebrate palæontology, Leidy's favorite field of research, all his great contributions antedate the beginnings of the work of Edward Drinker Cope and Othniel Charles Marsh, the two National Academicians whose names are always associated in our minds with his. His monograph of 1869, "On the Extinct Mammalia of Dakota and Nebraska," is, with the possible exception of Cope's "Tertiary Vertebrata," the most important palæontological work which America has produced.

ANCESTRY AND LIFE.

Descent from patriotic German-American stock enables us to understand the sources of Leidy's fine moral qualities. His remote ancestors, before 1720, were of the German peasantry. While he was chiefly of German extraction, his paternal grand-

mother, Catherine Le Febre Comret, was a sister of Francis Joseph Le Febre, Duke of Dantzig, Marshal under Napoleon I.

Intellectually Leidy inherited the sterling thoroughness generally characteristic of Teutonic science, the indomitable search for knowledge and love for the plain, unvarnished statement of fact, unclouded by speculation. In following up the immediate ancestry of Joseph Leidy we find, both on the father's and mother's side, well-to-do people, tillers of the soil, partly engaged in their own tanning and pottery. We also fail to find among his more remote military forebears any anticipation of his devotion to natural science unless it be that one of his great uncles was a surgeon, and that he was of the same parent stock as the German anatomist, Prof. Franz Leydig, of Wurzburg and Bonn. Leydig was Haeckel's master in embryology; his grandfather was a brother of Joseph Leidy's grandfather. It appears that Leidy's remarkable genius as an observer was not accumulative but was suddenly born with him. Of the many aspects of his character as a man of science we will speak more definitely after reviewing his life and works.

Joseph Leidy was born in Philadelphia on the 9th of September, 1823. His father was a hatter and is described as a man endowed with practical good sense, honest and industrious, but not of any conspicuous mental force nor of very great education. He was of ample means and never deprived his family of the wherewithal for their mental development. He was desirous that his sons should live independent, self-supporting lives, and naturally became concerned when he found Joseph preparing to support himself by teaching rather than by the practice of his profession as a physician. Certain it is that Leidy did not suffer from the financial strain which so many men of science experience in early life.

Joseph Leidy's mother, Catherine Mellick, was a woman of intellect and education, a descendant of the Mellicks (Moelich), also natives of Rhenish Germany, who founded the celebrated "Old Farm" in New Jersey and later emigrated to Pennsylvania. When Leidy was only a year and a half old his mother died, leaving behind her four children, of whom Joseph was the third. His stepmother, Christiana Mellick, was also an intelligent woman, and gave Joseph his early training until he

was sent to the private school of William Mann, a Methodist clergyman, where he received as good a preparatory training as Philadelphia afforded in that day. At this classical academy, where Latin and Greek formed the principal part of the instruction, Leidy did not distinguish himself in his studies, but showed an intense interest in all branches of natural history, although none of these subjects were included in the curriculum. It was his greatest delight to wander out into the rural districts of Philadelphia in quest of minerals, plants, insects, etc., and occasionally these excursions would tempt him to absent himself from school without leave. He was indifferent to boyish sports and devoted his leisure time to drawing the natural objects which he collected. A note-book has been preserved, dated 1833; it contains a series of careful drawings of snail shells and shows the degree to which Leidy, solely through his own efforts, had cultivated his natural abilities at the age of ten. In later years he became an expert draughtsman, especially of microscopic objects. When at the age of sixteen he left school his father determined that he should be an artist. His mother, however, wished her sons to "learn professions," and, as Leidy later explained, "she being the stronger carried the point."

About this time Leidy spent several months in a wholesale drugstore of a cousin physician and druggist, and soon acquired so accurate a knowledge of drugs that he was recommended to take temporary charge of a retail branch of the business; but from the skill he had already displayed in dissecting, which he had practiced on a few domestic animals, his mother believed that she saw in him the makings of a great physician and she prevailed on his father to allow him to take up the study of medicine. For a year he studied anatomy under a private teacher, Dr. James McClintock, and in 1841 he matriculated at the University of Pennsylvania. Here his chief instructor was Dr. Paul B. Goddard, who in leisure evenings at his own home introduced Leidy to the use of the microscope, which became thereafter one of the greatest pleasures of his life. In 1844 Leidy received the degree of doctor of medicine, after presenting a thesis on "The Comparative Anatomy of the Eye in Vertebrated Animals." He opened an office in Phila-

delphia, and for two years practiced the profession of medicine with little success. With ardent interest he continued to pursue his studies in comparative anatomy, for which his practice left him ample time, and also acted as prosector to the eminent Dr. Horner, professor of anatomy at the university.

Leidy's initial publications appeared, at the age of twenty-two, in the year 1845 in the Proceedings of the Academy of Natural Sciences of Philadelphia and of the Boston Society of Natural History, covering[a] new species of fossil shells from New Jersey,[b] the microscopic examination of a vertebra of a fossil Zeuglodon,[c] the anatomy of the snail *Helix albolabris,* the anatomy of the dart, and several species of American pneumobranchiate mollusks. This last paper, presented before the Boston Society of Natural History, showed so much ability that Leidy was immediately elected a member of the society. At this time, September, 1845, Amos Binney, president of the society, wrote him: "The value of the compliment of your election to membership in the Boston Society of Natural History consists in the wish to encourage you to continue to give some portion of your time to that branch of natural history in which there is no doubt that you may render essential service to science. I mean the comparative anatomy of the lower orders of animals."

On July 29, 1845, Leidy was also elected to membership in the Academy of Natural Sciences of Philadelphia, an important event alike in his history and that of the academy. He published the first of a long series of contributions, and for the succeeding forty-six years he exerted a most active influence on the well-being of the institution in every department, until in the world at large the names of Leidy and the academy became inseparably associated.

This recognition of the originality and breadth of Leidy's

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[a] Published in Proc. Boston Soc. Nat. Hist., 1845. (See bibliography.)

[b] Notes taken on a visit to White Pond, Warren County, New Jersey, [and a list of ten species of fossil shells collected there]. Proc. Acad Nat Sci Philadelphia, vol. 2, 1845, pp 279–281.

[c] [The microscopic examination of a portion of a vertebra of the fossil Zeuglodon shows that it has all the characteristics of recent bone.] Proc. Acad. Nat. Sci. Philadelphia, vol. 2, 1845, p. 292.

observations by the two leading scientific institutions of America truly marked the first turning point in his career. In these days when science has a recognized place in every university and school, and museum collections are available in all the large cities, it is difficult to realize how much the privileges of the academy library, apparatus, and collections, as well as the interest and coöperation of the specialists in its circle of members, could mean to the young scientist. The records of the academy show that Leidy regularly attended the weekly evening meetings from this time on and almost invariably took part in the discussions Soon after his election as a member Leidy was appointed librarian of the academy, and performed his duties in the conscientious and efficient way in which all his work was done. In later years he served the academy as chairman of the board of curators, and finally as president for two dates.

The six papers which Leidy contributed during the year 1846 cover the anatomy of the sloth and of one of the lemurs, the wings of the locust, the olfactory organs in one of the gasteropods, and include also his first two contributions to the knowledge of parasites which infest mammals.

From this early period dates Leidy's first discovery, which in a practical way has contributed more than any other to the welfare of humanity and has resulted finally in the saving of hundreds, even thousands, of lives annually. With his keen powers of observation he noticed in a piece of ham served at his breakfast table numerous minute white specks, which on examination under the microscope he recognized at once as cysts of *Trichina spiralis,* which were known to him from their occurrence in human muscles. In 1835 Richard Owen had described and named *Trichina* as parasitic in the human subject, but up to the time of Leidy's discovery no one had surmised the true source of this dangerous entozoön in man [a]

In the summer of 1846, at the age of twenty-three, Leidy visited Samuel Stehman Haldeman, making collections of animals and plants in the vicinity of his home, reports of which

[a] [On the existence of an Entozoon (*Trichina spiralis*) in the superficial part of the extensor muscles of the thigh of a hog.] Proc. Acad. Nat. Sci. Philadelphia, vol. 3, 1846, pp. 107–108.

appear in 1847 as his first contribution to the anatomy of marine vertebrates and invertebrates. It was at this time that through his dissections his attention was drawn to the existence of a fauna and flora within living animals, a subject which he selected for a special contribution in 1853. During the fifties he was a frequent visitor to Newport, Rhode Island, and Narraganset Bay, where much of his work on marine zoölogy was accomplished.

The year 1847 is also noteworthy for the appearance of Leidy's first two contributions to vertebrate palæontology,[a] the subjects being a fossil horse of the East and a fossil cameloid of the West (*Poëbrotherium*). This marked the beginning of his interest in palæontology and of those manifold observations and notes on the extinct vertebrates of every region of North America which fill the proceedings and memoirs of the Academy of Natural Sciences. At this time Cope was seven years of age and Marsh sixteen. Although Leidy's labors throughout his life extended over almost every field of zoölogical research, the complete list of his publications shows that the study of vertebrate palæontology absorbed his energies chiefly up to the year 1873, after which his time was again devoted chiefly to microscopic organisms, although he made occasional contributions to palæontology.

In 1847–1848 Leidy definitely decided to abandon the practice of medicine and to devote himself to scientific research and teaching, whatever financial difficulties might arise or as a consequence lie in his path. He therefore accepted an appointment as demonstrator of anatomy in the Franklin Medical College, which he surrendered, however, at the end of one session in order to resume his anatomical work under Dr. Horner at the University of Pennsylvania, and at the same time to deliver privately his first course of lectures on anatomy, human and comparative. His first notable contributions in this field were those of 1847 and 1849 on the evidence of the existence of the intermaxillary bone, confirming the earlier prophecy of Goethe.

[a] On the fossil horse of America (*Equus americanus*). Proc. Acad. Nat. Sci. Philadelphia, vol. 3, 1847, pp. 262–266.

On a new genus and species of fossil Ruminantia (*Poëbrotherium wilsoni*). Proc. Acad. Nat. Sci. Philadelphia, vol. 3, 1847, pp. 322–326.

Several contributions to human anatomy appear about this period (1848–1849), which prepared him, at the age of twenty-seven, for the editorship of the first American edition of Quain's "Human Anatomy."

The summer of 1848 was spent abroad, Dr. Horner having invited his young assistant to accompany him In London, Paris, Vienna, and other large cities, he visited the museums and hospitals and made the acquaintance of eminent anatomists and physiologists, among others Owen, Darwin, Majendie, Milne Edwards, and Johannes Müller. Leidy sailed for London on a packet ship, and soon after arrival he wrote a letter to Richard Owen in which he used the following appropriate expression: "Looking upon you as the Cuvier of England." Owen extended to him every courtesy. He dined with Owen and met Charles Darwin just before returning to America. In Paris he found himself in the midst of the rebellion of 1848, and in a long letter to his mother, describing the exciting events, he writes: "I got between the fires."

With his vision greatly broadened by this experience, Leidy returned to his work with increased energy. He delivered a course of lectures on microscopic anatomy, published the new edition of Quain's "Human Anatomy," and began a course of lectures on physiology at the Medical Institute of Philadelphia.

Indicating that he was a pioneer in this country in his special field of microscopy is a letter received in 1852 from the Italian anatomist, Corti: "I have not been aware of any one else in America interested in microscopic anatomy, and write to interest you in my investigation of the organ of hearing." [a]

After a short time overwork threatened Leidy with serious illness, and he was obliged to suspend his teaching, as well as his investigations, for some months. In the spring of 1850, at the age of twenty-seven, a second opportunity to travel abroad presented itself. Dr. George B. Wood, who had just been appointed professor of the practice of medicine in the University of Philadelphia, and who wished to make a collection in Europe of specimens, models, and drawings for his lectures, persuaded Leidy to accompany him.

[a] This was the only work that Corti published, as he relinquished scientific pursuits and entered the field of Italian diplomacy.

In the meantime an intimacy had sprung up with Spencer F. Baird. In 1853 Leidy wrote to Baird: "I am desirous of making a special library of vertebrate palæontology so far as my means will permit" In 1852 Leidy had arranged to accompany an expedition to the West to collect fossils. He particularly desired to enter the field, as he wished to make certain geological observations. We must consider it a great loss to science that he was unable to carry out his plan. As he was about to start Dr. Horner, professor of anatomy at the University of Philadelphia, became so seriously ill that Leidy was informed by his friends it was absolutely essential for him to remain as a substitute for Dr. Horner's course of lectures, as in the event of his death he would in all probability be called to the chair. Baird wrote to him: "Do not leave Philadelphia until you have settled the professorship," and added, "Do not worry about the fossil bones; they will all be sent to you anyhow."

It is characteristic of the dogmatic influences of the times that the rival candidate for the chair of anatomy was using Leidy's scientific researches as a weapon in opposing him. He writes to Baird: "All those things which you would think would recommend me to the trustees my opponent is using against me. I am shamefully abused as being an atheist, an infidel. It has been positively asserted that I seek to make *proselytes to infidelity*, and that in my writings I have tried to prove that geology overthrows the Mosaic account of the creation. You may judge of my feelings"

Aided by warm letters of recommendation from Wyman, Dana, and Henry, Leidy, although only thirty years of age, received the professorship of anatomy in 1853. Dana referred to him as the most eminent comparative anatomist in the country. Wyman wrote: "It may be added that Dr. Leidy is eminently distinguished as a man of science, with an ardent love of nature, with untiring industry, with quiet and accurate powers of observation. He combines a highly philosophical mind and great fidelity as a searcher after truth." Joseph Henry wrote: "If the regents, or rather the trustees, should be so blind to the best interests of the institution as to place some favorite over your head, they will repent it. If you con-

tinue to grow as you have begun, places of honor will be forced upon you"

At the age of forty, in August, 1864, Leidy married Anna Harden, of Louisville, Kentucky. They had no children.

When, in 1867, the Academy of Natural Sciences of Philadelphia was planning the erection of a new building, more ample accommodations for its growing museum and library, Leidy was appointed a member of the board of trustees of the building. The administrative duties connected with this post were little to his taste, and so far as possible he left all decisions to other members of the board, whom he considered more practical than himself.

In 1874 Leidy was offered the Hershey Professorship at Harvard. In 1875 he again went abroad, and during his visit to London he met Mrs. Huxley, Huxley himself being at the time in Edinburgh lecturing. The day following his call Leidy received a letter from Huxley, in which he expressed regret, and wrote in his characteristic way: "Mrs. Huxley once saw an iceberg, which I in all my travels never had a chance of, and I am really in despair missing all chance of seeing you. If she has also the power of boasting that she met you and I have not . . . my life will not be worth living. For domestic reasons if for no other, therefore, let me have the pleasure of seeing you."

In 1880 an invitation to lecture and supervise the studies of the graduate students of Princeton University was considered and declined.

Some of the most interesting episodes in Leidy's life may be considered in connection with his two chief lines of investigation, the protozoa and fossil vertebrates. His character and intellectual predispositions are constantly reflected in his work. His knowledge of the general facts of natural history was vast. While lecturing at Swarthmore the students would delight in trying to bring to his notice some natural object with which he might prove to be unacquainted, but they never succeeded in finding him unprepared. In scientific discussion he seemed to have an intimate and first-hand knowledge of every speciality, in addition to being a master of anatomy, invertebrate zoölogy, and palæontology. Although he did not claim to be a miner-

alogist his knowledge of minerals and precious stones was vast. He lectured at Swarthmore for years on minerals, and his collection of minerals, sold to the Smithsonian Institution after his death, reflected his keen powers of observation and judgment. He made one of the first collections of gems arranged in this country, to which he added from time to time until a few years before his death it was disposed of in Boston; some of these gems are now in the collection of the American Museum of Natural History of New York.[a]

Botanical studies continued to attract him. He once expressed regret at not having time to prepare a monograph on the "grasses," which interested him particularly.

Leidy's life continued to be characterized by unabated vigor and constant industry. Year after year the Proceedings of the Academy of Natural Sciences contained numerous short communications, with studies of parasitism and palæontology taking the most prominent place. In 1881 Leidy was unanimously elected president of the Academy of Natural Sciences of Philadelphia—an office which he held until his death, in 1891. When, in 1884, after almost twenty years of preparation, the University of Pennsylvania established a department of biology, Leidy was made its director, and was also appointed to fill the chair of zoölogy and comparative anatomy. In the following year the Wagner Free Institute of Science of Philadelphia elected him its president. Thus the prophet was honored in his own country, and Philadelphia may look back with satisfaction to her generous and timely recognition of the greatness of her son.

Accompanied by his wife, Leidy visited Europe for the last time in 1889. He returned home little refreshed and his strength began to fail soon afterward. Nevertheless he continued his teaching and the performance of his many duties until the week before his death.

Leidy passed away on April 30, 1891, in has sixty-eighth year, having continued his studies almost to the very last. The amount of work accomplished by him in his productive period of forty-six years (1845–1891) is extraordinary. His pub-

[a] See Memoir of Joseph Leidy by Persifor Frazer, American Geologist, January, 1892.

lished writings of various lengths exceed 600 titles. Although an indefatigable worker, he was devoid of personal ambition, and seems to have sought positions not for the distinction they might bring to him, but only for the opportunity which they might afford for the pursuit of his scientific studies. He frequently placed others before himself. When invited to make the opening address of the American Museum of Natural History in New York, he declined, advising the trustees to ask Professor Marsh in his stead To Meek and Hayden, who wrote to him in 1859 regarding credit for a geological observation, he replied: "I am too little ambitious to give myself any trouble about such a case as that you mention. Even should any one pass unnoticed more important things I may have done, I shall feel no regret about the matter."

He cared as little for money as for position, his tastes being extremely simple. He was simple and unassuming in habit from first to last and unaffected by the honors which came to him from every part of the world. The tributes paid to Leidy at the time of his death enable us to realize in what high esteem he was held as a man. It is said that he never made an enemy; the testimony of all with whom he came in contact is that he was as lovable as he was great in character. A love of peace was one of the essential characteristics of his nature, combined with a strong passion for truth and love of the beautiful. He disliked controversy exceedingly and was reserved on all matters relating to his personal beliefs, such as religion. The Unitarian Church appealed to him most strongly. To quote from his own words: "I have always had an antipathy to enter into a discussion of religious opinions, and when persons, curious to know mine, have questioned me, to avoid discussion, I have the last few years referred them to the admirable work of John Fiske [Cosmic Philosophy]. . . . Through life I have been conscious of having been a devoted worshiper (again to quote Mr. Fiske) 'of an ever-present God, without whom not a sparrow falls to the ground'; and I have often felt annoyed at the implied reproach of infidelity from the self-sufficient who consider that they fulfill all religious duty in lip service to the same Deity." It has been alleged that he resembled Darwin in a lack of appreciation of poetry, but

this appears to have arisen from a misunderstanding. Among his favorite writers were Longfellow and Holmes. "The Chambered Nautilus" of the latter had an especial charm for him. He was fond of art, and his own artistic skill was coupled with a keen delight in beauty of form and color

CONTRIBUTIONS TO ANATOMY.

In 1854, the year after his appointment as professor, Leidy was selected to represent the University of Pennsylvania at the meeting of the American Medical Association in St. Louis.

After his appointment he came to be regarded as one of the leading authorities on anatomy in America. His elementary treatises on human anatomy,[a] published in 1861, and republished in a large and revised edition in 1889, was for many years a classic text book for students of medicine, and even now repays study, though out of date in many of its statements. It is conspicuous for clearness, simplicity, and accuracy—features which characterized all of Leidy's writings.

During the Civil War Leidy volunteered as surgeon to the Satterlee Military Hospital, which was established in West Philadelphia. The task of superintending and reporting on the autopsies was assigned to him, and in the medical and surgical history of the war, published between 1870 and 1879, are contained the accounts of sixty autopsies performed by Leidy. Although he continued to hold the professorship of anatomy throughout his life and performed the duties connected with it in a more than creditable manner, his interests gradually drew him farther and farther from the subject of anatomy. After his report to the Surgeon General of the Army he wrote only one more paper directly connected with the science of medicine. As in his school days, it became his pastime to study almost every branch of natural history, and all his leisure was devoted to varied researches, which in retrospect seem to constitute the most voluminous portions of his work.

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[a] An Elementary Treatise on Human Anatomy. J. B. Lippincott Co., Philadelphia, 1861. Second edition, rewritten. J. B. Lippincott Co., Philadelphia, 1889.

CONTRIBUTIONS TO MICROSCOPY

Leidy's studies in helminthology continued to the last and gave him a very great reputation; specimens chiefly of parasitic worms were sent to him for determination from all parts of the United States. Some time previous to his death he had in contemplation the publication of a work upon helminthology and parasitology. In the early years of his researches in this field he was the only American naturalist who devoted any considerable time to these studies Leidy's plan of publication was never carried out, but we are indebted to Joseph Leidy, Jr., a nephew of the great anatomist, for bringing together, in the Smithsonian Miscellaneous Collections,[a] all of Leidy's published researches in this field, beginning in September, 1846, and continuing until 1891, the last year of his life. In 1853 Leidy published his first memoir in this field, entitled "A flora and fauna within living animals," [b] a volume beautifully illustrated by ten plates from Leidy's own drawings.

His first materials for the study of the Protozoa had been gathered in the East, in the pools and streams in the neighborhood of Philadelphia. During the years 1872–1873 he spent his summers in the region of Fort Bridger, Wyoming, and when obliged for a time to abandon the subject of vertebrate palæontology, he turned again to that division of the Protozoa known as Rhizopods.

Dr. F. V Hayden, director of the United States Geological Survey of the Territories, encouraged these researches and showed a very broad appreciation of the scope of the survey in publishing "Freshwater Rhizopods of North America" as volume 12 (1879) of the survey monographs. In introducing this monograph, Leidy observes: "During the last four years

[a] Researches in Helminthology and Parasitology by Joseph Leidy, M. D., LL D., professor of human and comparative anatomy and zoology in the University of Pennsylvania, president of the Academy of Natural Sciences, and of the faculty of the Wagner Free Institute of Science, Philadelphia, with a bibliography of his contributions to science. Arranged and edited by Joseph Leidy, Jr, M D. Smithsonian Misc. Coll., part of vol. 46, 1904, 281 pages.

[b] A flora and fauna within living animals. Smithsonian Contr. Knowl., vol. 5, 1853, pp. 68, 10 plates.

I have studied one important class—the Rhizopods as they occur in all fresh waters of the country from the Atlantic border to an altitude of 10,000 feet in the Rocky Mountains. The marine forms of Rhizopods, in all times, have extensively contributed to the construction of stratified rocks. The determination of the living fresh-water forms may serve as a guide to the discovery and determination of fossil forms in the vast lacustrine formations in the interior of our continent." The volume is beautifully illustrated with forty-eight large plates in color from Leidy's exquisite drawings. The work illustrates the simplicity of Leidy's methods when he observes that all his observations were carried on with a small microscope costing only $50, and that the total expense to which he put the Geological Survey during his explorations in the West amounted to $222. The spell which the work cast about him is shown in his concluding remarks: "I may perhaps continue in the same field or research and give to the reader further results, but cannot promise to do so; for though the subject has proved to me an unceasing source of pleasure, I see before me so many wonderful things in other fields that a strong impulse disposes me to leap the hedges to examine them." This culminated Leidy's study of this group, begun in his student days, when he had observed for the first time the amœboid motions of the white blood corpuscles.

One of his most important observations in the field of microscopy was presented in a brief note of May 5, 1886, under the title, "Remarks on parasites and scorpions." [a] Leidy described three specimens of worms obtained from an anemic cat, presumed to be specimens of *Ankylostoma duodenale,* which was sent to him by Dr. Belfield, of Chicago, for determination. He remarked:

> On superficial examination I supposed the worms might belong to *Strongylus tubæformis,* a closely related parasite infesting the cat. The specimens, however, exhibit the same structure of the mouth as is described in the *Ankylostoma duodenale* of man. . . . [Description follows.]
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> The finding of this parasite in the cat in this country renders it

[a] Remarks on parasites and scorpions. Trans. Col. Phys. Philadelphia, 3d ser., vol. 8, 1886, pp. 441–443.

probable that it may also infest man with us, and is probably one of the previously unrecognized causes of pernicious anemia

This communication was made by Leidy to the College of Physicians of Philadelphia before the full significance was recognized of the presence of the hookworm in man as a cause of anemia—a subject subsequently developed through the investigations of Dr. C. Wardell Stiles as of the first importance in medecine.[a]

Leidy, in alluding to the work of Dr. John K. Mitchell on the fungus origin of malaria, denied this origin and treated Mitchell's work as speculative, in which position he was correct. It is doubtful whether he entertained the idea that malaria could not be or was not of parasitic origin, because the etiology was not then known, and it would have savored too much of dogmatism. He remarks: "The production of certain diseases, however, through the agency of entophyta, is no longer a subject of doubt, as in the case of Muscardine in the silk-worm, the Mycoderm of *Porrigo favosa* in man, etc.; but that malarial and epidemic fevers have their origin in cryptogamic vegetables and spores requires yet a single proof.[b] If such were the case, these minute vegetables and spores, conveyed through the air and introduced into the body in respiration, could be detected[c] (p. 14)

Leidy had a marked interest in the problem of "spontaneous generation"; his work covered a long period at intervals of patient research work; his conclusions were referred to in the text and in the footnotes appended to the introduction of "A flora and fauna within living animals" (1853). He made an extended reference to further investigations in his address before the medical students of the university in a lecture published in 1858 and 1859.

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[a] "The worms from the cat were not *A duodenale* of man, but apparently *A caninum,* which is very common in dogs" C. W. Stiles, letter to H. F. Osborn

[b] See "an ingenious little work by my distinguished friend, Dr. J. K. Mitchell, 'On the cryptogamous origin of malarious and epidemic fevers."

[c] "A flora and fauna within living animals." Accepted for publication December, 1851. Smithsonian Contr..Knowl., vol. 5, Art. 2, April, 1853, pp. 67, 10 plates.

Prof. Henry B. Ward[a] gives the following estimate of the value of Leidy's work on the lower organisms:

His contributions to comparative anatomy among invertebrate groups are no less important, both among insects and mollusks he contributed investigations which form the basis of our present knowledge of these groups It was, however, among the lower forms that his work was particularly noteworthy Here he entered upon fields comparatively unbroken and achieved results of the highest permanent value His work on Protozoa is well shown in a magnificent monograph[b] whose artistic and accurate figures were all the work of his own pencil All his observations were made with wonderful precision in view of the simple instrument at his command Thus, for instance, he noted in 1849 and in 1851[c] that the Gregarinida are provided with muscle fibers, a view which was denied by European observers until thirty years later it was confirmed by the younger Van Beneden

In some respects his most striking work was done in the field of helminthology Among his very first papers was one in 1846 on an entozoan from the pig, in which he announced that he had discovered a minute encysted worm, which he regarded at *Trichina spiralis*, heretofore considered as peculiar to the human species This observation attracted the attention of Leuckart, who in his monograph gives due credit to Leidy, and suggested that trichinosis in man might be due to the eating of raw pork containing the parasite (pp. 273–274)

A series of helminthological contributions ran from 1850 to 1856, culminating in his Synopsis,[d] which is the only paper of its kind that has yet appeared in this country (p 274).

Prof. Gary N. Calkins writes:

There is really not much that I can add to what he [Ward] has given except a word of appreciation for his splendid work as a pioneer on American Protozoa His monograph on the rhizopods is a splendid production and will stand as a classic. It well illustrates his powers of careful observation, keen insight into the structures, and their bearings on the vital activities of these forms. Not only rhizopods, but many other types of Protozoa as well, are carefully noted and affinities made out. On the whole, Leidy's work is to be classed as taxonomic rather than biologic. His particular genius here seemed to be morpho-

[a] Ward, Henry B. Notices Biographiques, VIII. Joseph Leidy, M. D, LL D. Archives de Parasitologie, tome 3, 1900, pp 269–279.

[b] Fresh-water rhizopods of North America Rept. U. S Geol. Survey Territories, vol. 12, 1879, pp XII and 324, 48 pls.

[c] Proc. Acad Nat. Sci. Philadelphia, vol 4, pp. 226–233; and vol. 5, pp. 205–210.

[d] A synopsis of Entozoa and some of the ectocongeners. Proc Acad. Nat. Sci. Philadelphia, vol. 8, 1856, pp. 42–50.

logical, his quick eye noting any differences which might indicate novel types. It may be stated that Leidy was undoubtedly the foremost student of Protozoa in this country at his time—a fact which illustrates his wonderful breadth of view and keen interest in all things pertaining to natural history.[a]

To his helminthological work numerous references have already been made He brought together a vast amount of material and the studies made on this were communicated to the world mostly in the form of brief articles rather than finished contributions Nevertheless, his keen insight into comparative anatomy led him to outline many natural genera, such as *Clinostomum,* to which the newer generation of students are just returning as natural subdivisions. While these observations were made with great keenness of perception, it must still be confessed that they were often expressed in quite too brief form for clear general understanding. In this he only followed the plan of his European contemporaries, and while his ideas are distinct with the specimen itself in view, it is undoubtedly true, as in the case of many other great workers of the past generation, that the original specimens must be worked over more fully to establish their actual taxonomic position. It is sad to record that his helminthological work was left unfinished. In the five volumes of *Leidyana* presented to the Philadelphia Academy by Dr Nolan are included four volumes of drawings and notes which are a veritable mine of helminthological information. An unfinished monograph of the Gregarines is indicated by the 176 unpublished illustrations of these forms from twenty-one hosts which occur among these drawings, and the wide range of other helminthological work shows well that his project of a monograph on parasites would have given the world a work the loss of which we may well mourn But though unfinished, his contributions will form the basis of American work in the future as they have furnished in some directions even to the world the foundation for past work in this department. Leidy's reputation as a helminthologist was certainly cosmopolitan, as is clearly evinced by the numerous references to his contributions in the works of Cobbold, Diesing, and of that master of helminthology, Rudolph Leuckart (pp. 276–277).

Dr. C. W. Stiles gives the following estimate of Leidy's work:[b]

Our estimate of Leidy's work on parasites must vary with our point of view. If we belong to the class of students who try to judge the work of a broad general zoölogist of 1880–1890 from the point of view of a specialist of 1910, we must conclude that Leidy's results were inferior. If we belong to the class of students who recall that all efforts

[a] Letter to Professor Osborn, April 30, 1912.

[b] Letter to Professor Osborn, May 18, 1912.

should be judged in connection with their period, we must conclude that Leidy was not only the American pioneer, but a brilliant pioneer in this field of zoölogy

From a viewpoint of public health, his discovery of *Trichinella spiralis* in swine seems to be his most important practical contribution to helminthology. In addition, his systematic work had considerable value which for years was overlooked

His other great public-health contribution seems to me to be his observation on flies as apparent spreaders of disease It concerned flies in hospital wards during the war, 1861–1865, as spreaders of infection to wounds.

Leidy, in 1879, reached a stage in the classification of parasitic amœbæ which the rest of the world did not reach until years later. He recognized that parasitic amœbæ, like the amœbæ of the water-roach, should be separated from the free living forms, but I do not recall any modern author on amœbiasis who has seen this historical point.

Insects and protozoa as possible disease-carriers were constantly in Leidy's mind. Dr. Frank E. Lutz contributes[a] the following interesting notes gathered from twenty-three of Leidy's contributions on insects:

In most of Leidy's best work insects play the incidental rôle of hosts of the micro-animals and plants he was really investigating. He apparently was much interested in them as objects for observation, as is shown by the numerous short notes he presented before the Academy of Natural Sciences, but he wrote no important paper on a purely entomological subject. In 1846 he published two short but interesting notes on the anatomy of certain Orthoptera, and in 1852 made the suggestion that the disappearance of tracheæ from the replètes of the honey-ant prevented the digestion of the "stored" honey. In the same year he worked with Langstroth on the question of the fertilization of the eggs of the honey-bee, advocating the now accepted idea that spermatozoa are stored for some time in the spermatheca of the queen. In 1853 he discussed the cause of malaria and wrongly concluded that it is not of parasitic origin, but in 1871 he suspected the carrying of smallpox and gangrene by flies, proving that they do carry spores of the fungus *Peallus impudicus*.

CONTRIBUTIONS TO PALÆONTOLOGY.

Sir Charles Lyell's "Principles of Geology," published in 1839, appears to have exerted a direct influence upon Leidy, as upon Darwin and many others, in arousing his interest in ge-

[a] Letter to Professor Osborn, April 29, 1912.

ology. After Lyell had visited young Leidy in his home in Philadelphia he wrote to him in 1883: "Give serious attention and devote your time to palæontology." It is a piece of interesting history that in Leidy's address many years afterward to Sir William Flower, acknowledging the award of the Lyell Medal by the council of the Geological Society of London, he says· "I must add that I feel as if Sir Charles himself was expressing satisfaction in consideration of my having complied with his wish, when thirty years ago in my own home here he said he hoped I would devote my time to palæontology instead of to medicine."

Leidy's observations in palæontology were first directed to specimens found in a cave in Mississippi near Natchez, supposed to include fossil human bones, in 1845, and presented at a meeting of the Academy of Natural Sciences. The untrodden field of palæontology opened before him as his greatest opportunity. A number of stray memoirs, notable among them those of Vice-President Thomas Jefferson and Dr. Harlan, upon the extinct sloth of America, the *Megalonyx jeffersoni*, had already been published, but no systematic work or connected statement covering the remarkable extinct fauna of the eastern coast of our continent had as yet been attempted. From the scanty materials in the academy and from scattered specimens sent to him by amateur collectors, Leidy, in the year 1847, at the age of twenty-four, published his first important paper on the fossil horse of America, in which he proved beyond a doubt that the horse, though extinct at the time of the discovery of America, had existed on this continent in prehistoric times. This had been preceded by several palæontological notes—*e. g.*, November 18, 1845. We find him inquiring into the causes which may have brought about the extinction of the horses on our continent, and his inquiry was formulated as follows: "At present their existence is being fully confirmed; it is probably as much a wonder to naturalists as was the first sight of the horses of the Spaniards to the aboriginal inhabitants of the country, for it is very remarkable that the genus *Equus* should have so entirely passed away from the vast pastures of the western world, in future ages to be replaced by a foreign species to which the country has proved so well

adapted. It is impossible in the present state of our knowledge to conceive what could have been the circumstances which have been so universally destructive to the genus on one continent and so partial in its influence upon another." Twelve years later we find much the same proposition stated in the following words in Darwin's "Origin of Species": "For seeing that the horse since its introduction into South America has run wild over the whole country and has increased in numbers at an unparalleled rate, I asked myself what could so recently have exterminated the former horse under conditions of life apparently so favorable." [a]

Leidy's wide and accurate knowledge of human and comparative anatomy, together with his extraordinary power of detecting resemblances, enabled him to make remarkable deductions from even the fragmentary materials which were submitted to him. In the year 1847 he described the first cameloid (*Poebrotherium*) from the Oligocene of the Western Territories.

In 1848 there are two notices of western forms, and from this time on until 1870 all the great materials from the West came into Leidy's hands, affording him the unparalleled opportunity of laying the foundations of American palæontology. As early as 1846 there had appeared in the American Journal of Arts and Sciences the description by Hiram A. Prout of part of a jaw which the author referred to "*Palæotherium*," from the *Mauvaises Terres,* near the White River, Nebraska. This jaw subsequently was referred to Leidy and he distinguished it as *Titanotherium.* It has become the type of the titanotheres, one of the most important families of mammals which Leidy discovered. These early papers on the mammals of Nebraska proved to be of the greatest importance, because they served to draw the attention of scientists to the exploration of the rich fossil beds of the West. The history of early exploration is given in Leidy's memoir of 1869. The first bones were collected by amateur collectors and sent to the Academy of Natural Sciences. The first systematic scientific collections were made by Dr. John Evans (1849) and by Thad-

[a] See Angelo Heilprin's manuscript memoir, "Dr. Leidy's work in geology and palæontology."

deus Culbertson (1850); the latter, at the instigation of Spencer F. Baird, immediately sent the fossils to Leidy for study and description, remarking that he was the only anatomist qualified to make the determination. Leidy's observations on this collection were presented in a series of notices in the Proceedings of the Academy. Leidy described and figured the forms mentioned in his "Description of the Remains of Extinct Mammalia and Chelonia from Nebraska Territory," published in 1852, and his final report was in "The Ancient Fauna of Nebraska, a Description of Extinct Mammalia and Chelonia from the Mauvaises Terres of Nebraska," published in 1854. In this the oreodonts, rhinoceroses, elotheres, and horses, as well as the titanotheres (*Palæotherium*) and Testudinata, chiefly of the Lower Oligocene, but referred to the Eocene, were first described. It was in the same year, 1852, that Leidy had arranged to accompany an expedition to the West to collect fossils; he particularly desired to go in order to make his own observations on the occurrence of the fossil remains, and it must always be deplored as a great loss to science that he was unable to carry out these plans. His mind was now concentrated upon vertebrate palæontology. One by one he thoroughly established the distinction of the New World from the Old World forms, first in the Oligocene, then, as the field of exploration broadened, in the Miocene and Pliocene areas. In the meantime the mammals of the eastern Pleistocene were successively treated in short but clear descriptions, always accompanied by close comparisons with the living and extinct forms of the Old World. "The Ancient Fauna of Nebraska," accepted for publication by the Smithsonian Institution in 1852, appeared in 1854. This was his last synthetic contribution to the western mammals prior to the publication of his great memoir of 1869. In the meantime Leidy's work, "A Memoir on the Extinct Sloth Tribe of North America," was prepared in 1853 and published in 1855. This was a companion to his other important works, "A Memoir on the Extinct Dicotylinæ of North America," presented to the Philosophical Society in 1852 and published in 1853 also to his memoir "On the Extinct Species of American Ox," completed in 1852 and published in 1853 by the Smithsonian Institution.

Dr. F. V. Hayden's explorations in the Judith and Musselshell rivers of Missouri in 1855 yielded to Leidy the first knowledge of the Upper Cretaceous reptilian fauna, including the Crocodilia, the Iguanodontia, and carnivorous dinosaurs. The first comprehensive account of these animals was Leidy's memoir, "Extinct Vertebrata from the Judith River and Great Lignite Formations of Nebraska," published by the American Philosophical Society in 1860. It will be observed that at this time the whole western territory was comprised within Nebraska. Leidy's comprehensive review of eastern and western mammals was completely paralleled by his equally comprehensive examination of the eastern and western reptiles. In 1857 he began his monographic revision of the Cretaceous reptiles of the United States, which comprehended those of New Jersey, Maryland, Delaware, North Carolina, Georgia, Alabama, Mississippi, and Nebraska. The last embraces not only the Judith River forms, first described, but from other parts of the West, adding the mosasaurs, plesiosaurs, and many new types of Crocodilia and Testudinata to his previous description. The mosasaurs carried his work into the Middle Cretaceous. It is interesting to note that the commission to which this memoir was referred by the Smithsonian Institution included Louis Agassiz and Edward D. Cope, the latter destined to soon succeed Leidy in both the reptilian and mammalian field. While extremely valuable for its exact description, this memoir on the "Cretaceous Reptiles of the United States," published in 1865, was rather a synthesis of all existing knowledge and an exact description and determination of a very fragmentary series of types than an attempt at classification or determination of the relationships and habits of the animals described; in fact, the material was far too fragmentary to admit of philosophic work. Even in the hands of Owen the classification of the extinct Reptilia was in a rudimentary stage. Nevertheless, this memoir, taken with that on the reptiles of the Judith River, constitutes the foundation of the reptilian palæontology of America. Brief reference should also be made to Leidy's work on the eastern saurians, such as *Bathygnathus* ? (1853) and "Descriptions of some remains of fishes from the Car-

boniferous and Devonian formations of the United States," published in 1856 by the Academy of Natural Sciences.

It is important to note that in all these treatises, although not having visited the territory described, Leidy made a serious effort in conjunction with the geological work of Dr. F. V. Hayden to determine the geological levels of the forms described.

Leidy's grandest contribution to palæontology is his memoir of 1869, entitled "The Extinct Mammalian Fauna of Dakota and Nebraska." This not only covers all his own researches on the western forms, but embraces a complete synopsis on the mammalian palæontology of North America up to the year of publication, which is absolutely invaluable to the student of the history of the subject This synopsis of early palæontology in this country is a priceless repertoire of the first period of mammalian palæontology in America, what may be called the pre-Darwinian Period. The illustrations in thirty lithographic plates, executed under Dr. Leidy's direction, are masterpieces of accuracy and have served for all subsequent determinations. The materials for the work had been accumulating for twenty-three years; those of the synopsis of the mammalian remains of North America had been accumulating for a century and a half. The preparation of the work occupied Leidy, with various interruptions, for a period of seven years. In the preface we once more observe Leidy's regard for fact rather than theory:

> The present work is intended as a record of facts, in palæontology, as the authors have been able to view them—a contribution to the great inventory of nature No attempt has been made at generalizations or theories which might attract the momentary attention and admiration of the scientific community. We give this premonition at the outset, to prevent disappointment in those who might be expectant of more important results than we have obtained from the great amount of material at our command. We have endeavored to see and represent things correctly, nothing more, though we apprehend we have not been able to avoid the average amount of errors usual under such circumstances.

The geological introduction by Dr. F. V. Hayden illustrates the extremely rudimentary knowledge of geological succession

which prevailed at that time, the Tertiary rocks being divided into four groups as follows:

Loup River beds, 300–400 feet.................. Pliocene
White River group, 1,000 or more feet............. Miocene
Wind River deposits, 1,500–2,000 feet .... (?)
Fort Union or Great Lignite group, 2,000 feet........... (?)

Leidy himself, however, made a remarkably accurate presentation of the vertical range of species (p. 20). His subdivisions, A, B, C, D, E, and F, have been used largely by Matthew (1899).[a] Matthew's identification of the Hayden and Leidy stratification is as follows:

F = Loup Fork = Upper Miocene
E = Ticholeptus Zone = Middle Miocene
D = Lower Miocene
C = Leptauchenia Zone or Protoceras Zone = Upper Oligocene
B = Oreodon Zone = Middle Oligocene
A = Titanotherium Zone = Lower Oligocene

At the time, the deposits in Nebraska and Dakota were all considered of lacustrine origin, and Leidy shows his sagacity in pointing out the absence of the remains of birds and fishes, and the fact that the single reptile known is a land turtle. It is now believed that these deposits are flood-plain—an interpretation which accounts for the absence of aquatic forms. Leidy returns to this subject in his concluding remarks:

> . . . In this view of the formations we are led to inquire why they exhibit no traces of fishes or aquatic mollusca mingled with the multitude of relics of terrestrial mammals Even remains of the latter of decided aquatic habit are absent. With the exception of the marsh-loving rhinoceros and the beaver, no amphibious mammals have been discovered; not even the hippopotamus, whose remains are frequent in contemporaneous formations of Europe and Asia
>
> The constitution of the skeletons of most fresh-water fishes, though comparatively unfavorable to their preservation as fossils, can hardly be admitted as a sufficient reason for the total absence of their remains

[a] A Provisional Classification of the Fresh-water Tertiary of the West. Bull. American Mus. Nat Hist, vol. 12, Art. 3, March 31, 1899, pp. 19–75.

in the formations in question The conditions during which the formations of the Mauvaises Terres were deposited would appear to have been especially favorable for the preservation of the most delicate structures The mammalian fossils, in the perfect preservation of their original sharpness of outline without the slightest trace of erosion and the character of their containing matrix, indicate quiet water with a soft muddy bottom The chemical constitution, too, of the matrix and fossils indicate a petrifying quality in the mud and water favorable to the preservation of any animal skeleton

The absence of remains of fishes and aquatic mollusks in association with the mammalian fossils, both in the Niobrara and Nebraska formations, may be accounted for by supposing that the lakes in which were formed the deposits containing the fossils may have been periodically subjected to admissions of salt water from the ocean, thus inducing a condition unfavorable to life in the lake waters.

He comments on the absence of crocodiles He also introduces a few generalizations. It is noted that in the form of the skull the Oligocene forms present a greater uniformity of structure than the existing mammals A valuable classification based on the system of Richard Owen is presented. A dissimilarity of the Oligocene and closer similarity of the Pliocene mammals to those of the Old World is noted. The presence of sloths is attributed to South American migration. Community of fauna with Europe is explained by a continental connection with Asia. The extinction of a very large part of the Oligocene fauna is commented upon.

The next great volume of Leidy was his "Contributions to the Extinct Vertebrate Fauna of the Western Territories," begun in 1870 and completed in 1873 [a] As early as 1868, Dr. J. van A. Carter, of Fort Bridger, Wyoming, in correspondence with Leidy, had informed him of the frequent occurrence of the remains of turtles and other animals in the buttes of the neighboring country. During the same year Hayden commenced his geological observations in these great Middle Eocene deposits, now known as the Bridger formation, which opened a new chapter in the history of the American fossil vertebrates. Leidy's first notice of these fossils appeared in the Proceedings of the Academy of Natural Sciences, April, 1869, in the mention of a little supposed Insectivore, *Omomys*

[a] Contributions to the extinct vertebrate fauna of the Western Territories. Rept. U. S. Geol. Surv. Terr, vol 1, 1873, 40, pp. 358, pls. 37.

carteri, which he named after Dr. Carter. The animal has since been determined as belonging to the Primates. Descriptions of many other forms appear in the Proceedings of the Academy of Natural Sciences of 1870–1873, followed by the publication of the memoir. When the volume was ready for the press, in the summer of 1872, Leidy received an invitation to visit Dr. Carter at Fort Bridger, which he accepted with delight, and thus on the eve of the publication of his last great work on palæontology he beheld for the first time one of the grand fossil-bearing regions of the West Referring to an excursion into the Badlands, he writes:

> No scene ever impressed the writer more strongly than the view of one of these Badlands . . . On ascending the butte to the east of our camp, I found before me another valley—a treeless barren plain, probably ten miles in width From the far side of this valley, butte after butte arose and grouped themselves along the horizon, and looked together in the distance like the huge fortified city of a giant race. The utter desolation of the scene, the dried-up water-courses, the absence of any moving object, and the profound silence which prevailed, produced a feeling that was positively oppressive. When I then thought of the buttes beneath my feet, with their entombed remains of multitudes of animals forever extinct, and reflected upon the time when the country teemed with life, I truly felt that I was standing on the wreck of a former world (p. 18–19).

There follows a vivid description of the geology of the Basin which makes one regret that Leidy's first opportunity to visit the region had come so late in his life. The volume is mainly devoted (pp. 27–196) to the Eocene fauna, mammals, reptiles, and fishes, but there occurs also the first systematic account (pp. 210–226) of the mammals of the John Day River, Oregon. now known to be of Upper Oligocene age. The Miocene and Pliocene vertebrates determined by Leidy after the close of his memoir of 1869 are also treated (pp. 227–264). The volume concludes with Leidy's last contribution to the vertebrate fauna of the Cretaceous period (pp. 266–309) and a notice of Carboniferous fishes (pp. 311–313).

This important monograph therefore completes the foundations which Leidy laid down for the systematic determination of the extinct vertebrate life of America. Already, in 1872, Marsh and Cope had begun to collect in the Bridger Eocene

field, and Leidy prophetically observes in his preface: "The investigations and descriptions by these gentlemen of some of the fossils from the same localities have been so nearly contemporary with mine that from want of the opportunity of comparison of specimens we have no doubt in some cases described the same things under different names and thus produced some confusion, which can only be corrected in the future." It has required nearly forty years of painstaking work to correct the confusion which Leidy refers to in this kindly note.

Marsh's contributions to western palæontology were begun in 1868.[a] Marsh had begun publishing in 1861. Cope began publishing in 1859, and it is noteworthy that his first paper on western vertebrates also appeared in 1868. While no doubt Leidy watched with keen satisfaction the promise of the development of the science in the hands of these younger men, an element of pathos entered into his own position. For the long period of twenty-one years (1847–1868) he had enjoyed a monopoly of vertebrate palæontology in America. Now the situation is suddenly changed; two younger men, full of energy and enthusiasm and with ample means, render it impossible for him to compete in the collection of fossils or to continue his best loved work Sir Archibald Geikie, who visited Philadelphia in 1879, quotes Leidy's own words in explanation of his abandoning palæontology at this time: "Formerly," he said, "every fossil one found in the States came to me, for nobody else cared to study such things; but now Professors Marsh and Cope, with long purses, offer money for what used to come to me for nothing, and in that respect I cannot compete with them. So now, as I get nothing, I have gone back to my microscope and my Rhizopods and make myself busy and happy with them." Leidy's bibliography attests the truth of this statement. In 1874 there appear seventeen papers on Rhizopods and other microscopic forms and only four on fossil vertebrates. His active work between 1874 and 1879 culminated in his memoir, "Fresh-water Rhizopods of North Amer-

[a] Notice of a new and diminutive species of fossil horse (*Equus parvulus*) from the Tertiary of Nebraska. American Journ. Sci., vol, 46, 1868, pp. 374–375

ica," of 1879 In the meantime, however, he began to renew his notices of vertebrate remains of the Eastern States, especially from the phosphate beds of South Carolina, which he collected in his two memoirs of 1874 and 1879[a] In 1880 he describes the fauna of the bone cave in Pennsylvania and gives a second paper on *Bathygnathus.* Occasional contributions follow in succeeding years on the horses and peccaries, and in 1884 there begin his notices of the vertebrate fossils from Florida, which continued until 1889, when Leidy's last important contributions to vertebrate palæontology were published in the Transactions of the Wagner Free Institute of Science[b] By an interesting coincidence these animals, which were partly obtained by Leidy's intimate friend, Mr. Joseph Willcox, were closely related to those from the Loup Fork of Nebraska, which Leidy had begun to describe in 1856, forty years before.

EVOLUTION

From the time of his first paper of 1847 on the fossil horse of America until his last paper of 1889, "On Hippotherium and Rhinoceros from Florida," Leidy was constantly accumulating facts for Darwin. It was a common saying that it is "a simple matter to construct the building after the materials are supplied." As a close observer of affinities of structure he anticipated by many years both Cope and Marsh in building up the materials for the phylogeny of the horses, camels, rhinoceroses, and other groups of ungulates. There does not seem to be a single case in which Leidy failed to recognize affinity. He showed extraordinary acuteness in distinguishing the various

[a] Description of vertebrate remains chiefly from the phosphate beds of South Carolina. Journ. Acad. Nat Sci. Philadelphia, vol. 8, 1877, pp. 209–261.

Notice of a new and diminutive species of fossil horse (*Equus parvulus*), from the Tertiary of Nebraska American Journ. Sci., 2d ser., vol. 46, 1868, pp. 374–375.

[b] Description of mammalian remains from a rock crevice in Florida. Trans. Wagner Free Inst. Sci. Philadelphia, vol. 2, 1889, p. 15.

Description of vertebrate remains from Peace Creek, Florida. Idem, pp. 19–31.

Description of some mammalian remains from the salt mine of Petite Anse, Louisiana. Idem, pp. 33–40.

genera of Miocene and Pliocene horses; many of his determinations which were formerly questioned are now thoroughly established, yet with our understanding of Leidy's nature it is not surprising that he failed to place these animals in phyletic or successive stages and virtually left this phyletic reconstruction entirely to Cope and to Marsh. We may explain this partly by Leidy's indisposition to indulge in controversy, because he well knew that evolution was a keenly controverted question, partly by his unwillingness to indulge in theories which he did not consider thoroughly tested by facts; but chiefly it is attributable to his thoroughly Teutonic disposition to confine himself absolutely to direct observation and to amassing as large a number of well-attested facts as possible. He spent his life in amassing facts. He was often approached by this or that firm or representative of some book concern or journal to give expression to some new theory. His invariable reply was: "I am too busy to theorize or to make money. The time will come when such investigations as I may add from time to time may prove of value, and I believe I can do more good to science in adding some new facts than in preparing articles for popular treatises." The correspondence of Leidy with Hayden confirms this view. There is little doubt that during this entire formative period Leidy was practically an evolutionist, although the theory was not clearly formulated in his mind. He could hardly have been less, in view of his familiarity with the second volume of Lyell's "Principles of Geology." In this connection it is interesting to observe what Leidy, in prophetic vein, wrote in his memoir, "A Flora and Fauna within Living Animals," published in 1853, eight years before the publication of "The Origin of Species":

The study of the earth's crust teaches us that very many species of plants and animals became extinct at successive periods, while other races originated to occupy their places. This probably was the result in many cases of a change in exterior conditions incompatible with the life of certain species and favorable to the primitive production of others. Living beings did not live upon earth prior to their indispensable conditions of action, but wherever these have been brought into operation concomitantly, the former originated. Of the life present everywhere, with its indispensable conditions and coeval in its origin with them, what was the immediate cause? It could not have existed

upon earth prior to its essential conditions, and is it therefore the result of these? There appear to be but trifling steps from the oscillating particle of organic matter to a Bacterium; from this to a Vibrio; thence to a Monad, and so gradually up to the highest orders of life. The most ancient rocks containing remains of living beings indicate the contemporaneous existence of the more complex as well as the simplest of organic forms; but, nevertheless, life may have been ushered upon earth through oceans of the lowest types long previously to the deposit of the oldest Palæozoic rocks as known to us.

With Asa Gray, he was among the very first to accept Darwin's theory of the origin of species; for immediately after the appearance of the first edition of Darwin's work, in 1859, upon the recommendation of Leidy and of Dr. Isaac Lea, Darwin was elected a member of the Academy of Natural Sciences of Philadelphia, March 27, 1860. Thus the Academy was one of the first institutions to honor Darwin after the publication of his great work Of this support Darwin wrote to Sir Charles Lyell:

MY DEAR LYELL: This morning I got a letter from the Academy of Natural Sciences Philadelphia announcing that I am elected a correspondent member It shows that some naturalists do not think me such a scientific profligate as many think me here.

Yours gratefully, CHAS. DARWIN.

In March, 1860, Darwin himself wrote a letter to Leidy referring to his early accounts of the horse and camel tribes.

HONORS.

In the year 1869 the honorary degree of LL. D. was conferred on Leidy by the Franklin and Marshall College of Lancaster. Not long after this he received his appointment as professor of natural history in Swarthmore College, and for fourteen years he lectured once or twice weekly to the students. His reputation kept steadily growing on both sides of the Atlantic and each fresh volume brought him new fame. In palæontology he was held as the Cuvier of America, while as an anatomist and zoölogist he was held in high esteem. In 1863 Leidy became one of the fifty leading men of science of America who joined in the incorporation of the National Academy of Sciences (March 3, 1863). When he went abroad in

1875 for the third time his acquaintance was sought by scientists everywhere In 1879 he was elected an honorary member of the Royal Microscopical Society of London, of the Zoological Society of London in 1883 In the year 1880 the Boston Society of Natural History awarded to him the Walker Grand Prize for 1879 for prolonged investigations and discoveries in zoölogy and palæontology, and in consideration of the extraordinary merit of Leidy's works the sum awarded was $1,000. In 1884 the Geological Society of London awarded to Leidy its Lyell Medal in recognition of his researches in geology and palæontology. In announcing the award of the medal, Sir Archibald Geikie said: "Among the scientific laborers in the palæontological harvest field, Dr. J. Leidy has held a foremost place. Careful in observing, accurate in recording, cautious in inferring, his work has the high merits which trustworthiness always imparts." This award was followed not many years afterward by that of the Cuvier Prize Medal, sent to Leidy by the Institute of France. In 1886 Harvard University conferred on Leidy the honorary degree of LL.D.

BIOGRAPHIES AND BIBLIOGRAPHIES OF JOSEPH LEIDY.

The present writer is chiefly indebted to Dr. Joseph Leidy, Jr., a nephew of Leidy, for many of the personal references in the above review, as well as for calling attention to the dates of some of Leidy's most important discoveries. The bibliography prepared by Dr. Leidy for his important review of the elder Leidy's work, entitled "Researches in Helminthology and Parasitology, by Joseph Leidy, M. D., LL. D.," is the most complete which has been published, and is reprinted herewith, with corrections and the addition of a few omitted titles.

The writer is indebted also to Dr. Joseph Willcox, of Philadelphia, an intimate friend of Leidy's, for an opportunity to examine the journal taken on Leidy's last journey abroad and for some interesting personal experiences.

On the whole, the memoir of Joseph Leidy prepared by the late Dr. Henry C. Chapman for the Academy of Natural Sciences is the most authentic of the ten which have been prepared and published by various writers. It appears that W.

Ruschenberger's sketch for the American Philosophical Society contains some matter which is less authentic. The most appreciative reviews of Leidy's contributions to geology and palæontology are those of Persifor Frazer (1892), of Angelo Heilprin (unpublished address), and of Archibald Geikie (1892). Relating especially to Leidy's contributions to helminthology is the brief memoir by Henry B. Ward, prepared for the French Archives de Parasitologie (1900). The memoir by Dr William Hunt was published for private distribution. There is also a biographical note in Spitzka's "Study on Brains," published by the American Philosophical Society. The fullest information regarding the life of Leidy will, however, be found in the biography now in course of preparation by Dr. Joseph Leidy, Jr.

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1846

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On the mechanism which closes the membranous wings of the genus *Locusta* Idem, p. 104. (Illustrated.)

[On the existence of an Entozoon (*Trichina spiralis*) in the superficial part of the extensor muscles of the thigh of a hog.] Idem, pp. 107–108.

On the situation of the olfactory sense in the terrestrial tribe of the gasteropodous mollusca Idem, pp 136–137.

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[Description of *Distoma helicis,* an Entozoon found in the pericardium of *Helix alternata*] Idem, pp 220–221

[Observations on the structure of the intervertebral substance of man.] Idem, p 243.

[Observation on the anatomy of *Squatina dumérili* exhibited.] Idem, p. 247.

Description and anatomy of a new and curious sub-genus of *Planaria* Idem, pp. 248–251.

Description of two new species of *Planaria.* Idem, pp 251–252.

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[On *Rhinoceros occidentalis*.] Idem, p. 119 (5 lines).

[Observations on the nettling organs of Hydra.] Idem, pp 119–121.

[On some fossil mammalian remains, *Rhinoceros nebraskensis*, *Palæotherium proutii*, and *P. bairdii*, *Merycoidodon culbertsonii*, and *Agriochœrus antiquus*.] Idem, pp 121–122

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[On *Emys culbertsonii*, a new species of fossil turtle] Idem, p. 34 (11 lines).

[On *Delphinus conradi* and *Thoracosaurus grandis*] Idem, p 35

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[On *Pontogeneus priscus*] Idem, p. 52 (12 lines)

[On the species of Hippopotamus] Idem, p 53 (12 lines)

[On *Troglodytes gorilla*.] Idem, p. 53 (4 lines)

[On Fossil Tortoises.] Idem, p 59

[On the "Red Snow" from the Arctic regions.] Idem, p 59 (6 lines)

[Extinct species of Ox, and *Bootherium*, a new genus] Idem, p 71 (14 lines).

[On the Honey Ant of Mexico.] Idem, p. 72 (12 lines).

[On *Tapirus haysii*.] Idem, p 106 (3 lines)

[On *Bison latifrons* and *Bison antiquus*] Idem, p. 117 (11 lines)

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[Remarks on *Echinococcus hominis*] Idem, p 12 (9 lines)

[Remarks on disease of the scales of minnows] Idem, pp 12–13.

[Remarks on growth of hairs on the cornea of an ox] Idem, p 15 (4 lines).

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1863

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On specimens of *Nostoc pruneiforme*. Idem, p. 281 (2 lines).

1865.

[On the existence of a boring sponge during the Cretaceous period.] Proc Acad Nat Sci. Philadelphia, vol 17, p 77 (5 lines)

[On the fossil horse, *Equus occidentalis*] Idem, p 94

[On a Kjokkenmodding] Idem, p. 95.

[On a fœtal dog shark, *Acanthias americanus*] Idem, p. 175 (10 lines)

[On fossil rhinoceroses Description of *Rhinoceros meridianus* and *Rhinoceros hesperius*] Idem, pp 176–177

[On specimens of oolitic phosphates of lime and alumina] Idem, p. 181 (8 lines).

[On cryolite] Idem, p 181 (4 lines).

[On human bones from a guano deposit on the Island Orchilla, W. I.] Idem, pp. 181–182

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1866.

[On a human skull of the so-called pigmy race.] Proc. Acad. Nat Sci. Philadelphia, vol 18, p 1.

[On a foot bone of *Hadrosaurus* from Columbus, Miss.] Idem, p. 9

[Cancer of the liver found in a turkey, with remarks upon *Trichina* and other Parasites.] Idem, p. 9.

[Remarks upon fossil bones of the elephant, etc., found in a salt mine on the Island of Petite Anse, Louisiana] Idem, p 109

[Observations upon a small collection of fossils from Bangor, Maine.] Idem, p. 237.

[Exhibition of teeth of *Mastodon ohioticus* from Big Bone Lick, Ky.] Idem, p 290 (5 lines).

[On *Drepanodon* or *Machairodus occidentalis*] Idem, p. 345 (6 lines).

1867.

[On fossil Hippopotamus] Proc. Acad. Nat. Sci. Philadelphia, vol. 19, p 32 (4 lines).

[On *Bison latifrons* and the skull of *Bison antiquus*] Idem, p. 85

[On the seventeen-year Locust] Idem, p. 93 (2 lines).

[On a fossil skull of *Geomys bursarius*.] Idem, p. 97 (6 lines).

[On a fossil skull of *Castoroides ohioensis*] Idem, pp 97–98.
[Remarks on antique copper implements.] Idem, p 97 (9 lines)
[Reference to specimens of black hornstone.] Idem, p 125 (4 lines).

1868.

[On *Sombrero guano*] Proc. Acad. Nat. Sci. Philadelphia, vol 20, p. 156 (5 lines).
Notice of some Vertebrate remains from Harden Co, Texas. Idem, pp. 174–176.
Indications of an *Elotherium* in California. Idem, p. 177
Notice of some reptilian remains from Nevada Idem, pp 177–178.
Notice of some Vertebrate remains from the West Indian Islands. Idem, pp. 178–180.
Notice of some remains of Horses. Idem, p. 195.
Notice of some extinct Cetaceans. Idem, pp. 196–197.
Remarks on jaw of *Megalosaurus*. Idem, pp. 197–200.
Remarks on *Conosaurus* of Gibbes. Idem, pp. 200–202.
Notice of American species of *Ptychodus*. Idem, pp. 205–208
Synopsis of Mammalian remains of North America. Idem, p. 202 (Announcement.)
[On the stomach of shad containing small fish.] Idem, p. 228 (9 lines).
Notice of some American Leeches Idem, pp. 229–230.
Notice of some remains of extinct *Pachyderms*. Idem, pp. 230–233.
On Coprolites from the Huronian slates. Idem, p. 302
On the cause of iridescence in opals. Idem, p. 303.
On asterism in mica. Idem, p. 313
On remains of extinct *Insectivora*. Idem, p. 315.
On *Wolffia columbiana*, the smallest and simplest of all flowering plants. Biological and Microscopial section, Acad. Nat. Sci. Philadelphia, pp. 6–7.
[A new species of sponge, *Pheronema annæ*.] Idem, pp. 9–10.
On *Euglena*. Idem, p. 11.

1869.

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1870.

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Gunshot wound of rib, with autopsy and specimen Idem, p 569.
Gunshot flesh wound, with autopsy Idem, Part II, vol 2, p 439 (5 lines)
Excision of Humerus necrosed after gunshot wound, with autopsy. Idem, p 596 (10 lines).
Gunshot wound of forearm, with autopsy and specimen Idem, p 927 (7 lines)
Contributed specimen of Ulna successfully excised on account of gunshot wound, with report of the case Idem, p 962 (4 lines)
On the *Elasmosaurus platyurus of Cope* American Journ Sci, 2d ser, vol 49, p 392
[Description of *Megacerops coloradensis.*] Proc. Acad Nat. Sci. Philadelphia, vol. 22, pp 1–2.
[On *Poicilopleuron* and other fossils, *Clidastes, Leiodon, Emys,* etc.] Idem, pp. 3–5.
Remarks on *Elasmosaurus.* Nature, vol. 2, p 249
[On fossil bones of extinct giant sloths resembling *Mylodon robustus*] Proc Acad. Nat Sci Philadelphia, vol 22, pp. 8–9
[On *Diomatherium sylvestre*] Idem, p 9 (12 lines)
[On the reptile from the Cretaceous formation near Fort Wallace, Kansas, described by Professor Cope under the name of *Elasmosaurus platyurus*] Idem, pp 9–10
[On a fossil mandible, *Palaeofelis ulta,* from Fort Bridger, Wyoming.] Idem, pp. 10–11.
[Observations on *Ichthyodorulites.*] Idem, p. 12.
[On *Megalonyx jeffersoni* and *Bison antiquus.*] Idem, p. 13.
[On *Discosaurus* and its allies] Idem, p 18. American Journ Sci., 2d ser., vol. 50, pp. 139–140.
The Gordius, or Hair-Worm. The American Entomologist and Botanist, vol 2, No 7, May, 1870, pp 193–197.
[Description of the internal generative organs of a hog] Proc. Acad. Nat. Sci. Philadelphia, vol. 22, p 65
[On fossil bones from the Pliocene formation in Dakota and Nebraska] Idem, pp. 65–66
[On fossil Mammalia from Idaho, Utah, and Oregon.] Idem, pp. 66–67
[On *Hadrosaurus* and its allies.] Idem, pp. 67–68
[On the family Anguillulidæ, a new species of vinegar eel.] Idem, pp. 68–69.
[On fossils from the vicinity of Burlington, Kansas, and from the Rocky Mountains] Idem, pp. 69–71.
[On the difference between animals of the same species inhabiting Europe and America.] Idem, p. 72.
[On a fossil lower jaw of a large ruminant, *Ovibos cavifrons.*] Idem, p. 73.
[On *Nothosaurops occiduus.*] Idem, p. 74.
[Description of *Nephelis punctata,* a new leech.] Idem, pp. 89–90.

[On Mastodon remains in the Warren Museum, the museum at Cambridge, and at Amherst College, and on a new species of Mastodon.] Idem, pp 96–99

[On *Crocodilus elliotti*, a new species of crocodile] Idem, p 100

[Observations on *Manayunkia* and *Urnatella*] Idem, pp 100–102.

[On fossils from Sweetwater River, Wyoming] Idem, pp 109–110

[On fossils from Bridge Creek, Oregon] Idem, pp 111–113

[On *Cordylophora.*] Idem, p. 113 (13 lines)

[Description of *Palæosyops paludosus, Microsus cuspidatus,* and *Notharctus tenebrosus,* etc, and observations in reference to fossils from Fort Bridger] Idem, pp 113-114.

[On *Graphiodon vinearis* and *Crocodilus elliotti.*] Idem, p. 122.

[On *Emys jeanesi, Emys haydeni, Baena arenosa, Saniwa ensidens,* with a description of the new fossil species.] Idem, pp. 123–125.

[Observations on fossils from Table Mountain, Cal, submitted for examination by Prof J. D. Whitney.] Idem, p. 125

[On *Lophiotherium sylvaticum,* a fossil pachyderm from Wyoming] Idem, p. 126.

[On *Protohippus* and *Hippidion*] Idem, p. 126

Observations on a human inferior *Maxilla,* having imbedded in its substance a perfect third molar tooth. Idem, p. 133 (12 lines).

On reversal of the viscera in the human subject. Idem, p. 134 (8 lines).

1871.

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[On fossil bones from California—Mastodon, Horse, etc.] Proc. Acad. Nat. Sci. Philadelphia, vol. 23, p. 50.

[On *Tænia mediocanellata.*] Idem, pp. 53–55.

[On extinct fossil turtles from Wyoming *Anosteira ornata* and *Hybemys arenarius.*] Idem, pp 102–103.

[On Polydactylism in a horse] Idem, p. 112.

Remains of mastodon and horse in North Carolina. Idem, p. 113.

Remains of extinct mammals from Wyoming [*Trogosus* and *Sinopa*]. Idem, pp. 113–116.

Remarks on a fossil *Testudo* of Wyoming. Idem, p. 154.

Remarks on supposed fossil turtle eggs. Idem, pp. 154–155.

Remarks on the Garnets of Green's Creek, Delaware Co Idem, p. 155.

Remarks on donation of fossils from Wyoming Idem, p. 197.

Remarks on mastodon, etc., of California. Idem, pp 198–199.

Note on *Anchitherium.* Idem, p. 199 (8 lines)

Remarks on fossil vertebrates from Wyoming. Idem, pp. 228–229.

Notice of some extinct rodents. Idem, pp. 230–232.

Remarks on the minerals of Mount Mica. Idem, pp. 245–247.

Remarks on fossils from Oregon. Idem, pp. 247–248.

Flies as a means of communicating contagious diseases. Idem, p. 297.

Notice of some worms (*Dibothrium cordiceps, Hirudo, Gordius*). Idem, pp 305-307.

Tænia caused by the use of new beef. American Journ Med Sci., 2d ser, vol 44, p. 293.

Remarks on some curious sponges. American Nat, vol. 4, pp 17-22, 3 figures.

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On a mite in the ear of the ox *a.* Note on *Gamasus* of the ox Proc. Acad Nat. Sci. Philadelphia, vol. 24, pp 9 and 138.

Notice of corundum Idem, p 19.

Remarks on fossils from Wyoming. Idem, pp. 19-21

Remarks on some extinct mammals [from the Tertiary of Wyoming]. Idem, p. 37.

Remarks on some extinct vertebrates [from Niobrara River, *Felis augustus, Oligosimus grandævus,* and *Tylosteus ornatus*]. Idem, pp 38-40.

Remarks on mastodon from New Mexico Idem, p. 142.

On a new genus of extinct turtle (*Chisternon*) Idem, p. 162.

On some remains of Cretaceous fishes. Idem, pp. 162-164.

On *Artemia* from Salt Lake, Utah [and on fossil shark's teeth]. Idem, pp. 164-166.

Remarks on fossil shark teeth. Idem, p. 166.

Letter dated Fort Bridger, Uinta County, Wyoming, July 24, 1872, from Dr. Leidy to Mr. G. W. Tryon, Jr, in reference to fossil mammals found there. A copy of this letter Dr. Leidy sent to the American Journal of Science and Arts, because in it he referred to *Elasmosaurus platyurus,* Cope. Idem, pp. 167-169

Remarks on the habits of an ant [at Fort Bridger]. Idem, p. 218.

Remarks on mineral springs, etc, of Wyoming and Utah. Idem, pp 218-220.

Notice of a corundum mine [in Chester County, Pennsylvania]. Idem, pp 238-239.

Remarks on fossil mammals from Wyoming [*Uintatherium* and other fossil remains]. Idem, pp 240-241.

Remarks on chipped stones from Wyoming. Idem, pp. 242-243.

Notice of donation of fossils from Wyoming. Idem, pp. 267-268.

Remarks on fossils from Wyoming. *Palæosyops junior, Uintacyon edax, U. vorax,* etc. Idem, pp. 277-278.

On the fossil vertebrates of the early Tertiary formation of Wyoming [5th Annual] Preliminary Rept. U. S. Geol. Survey Montana and portions of adjacent Territories, Washington, 1872, pp. 353-372.

Notice of some parasitic worms collected during Professor Hayden's expedition to the Yellowstone River in the summer of 1871. Idem, pp. 381-382.

1873.

Notice of fossil vertebrates from the Miocene of Virginia. Proc. Acad. Nat. Sci Philadelphia, vol. 25, p. 15.

Notice of remains of fishes in the Bridger Tertiary formation of Wyoming. Idem, pp. 97–99.

Remarks on the occurrence of an extinct hog in [the Pliocene sands of Niobrara River, Nebraska]. Idem, p 207

[On bituminous coal from Westmoreland] [Of a black rat (*Mus rattus*), and note on Dufreynite.] Idem, p. 257.

Remarks on extinct mammals from California. Idem, pp. 259–260.

Fungus parasite on a mouse Idem, p. 260.

On *Distoma hepaticum* Idem, pp. 364–365.

On *Lingula* in a fish of the Susquehanna. Idem, pp. 415–416.

Remarks on fossil elephant teeth. Idem, pp. 416–417.

On circulatory movement in *Vaucheria*. Idem, p. 420

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Remarks on Protozoa Idem, pp. 13–15 (13 lines).

On the mode of growth of Desmids. Idem, p 15.

On *Actinophrysol*. Idem, pp. 23–24.

[Criticism of Professor Cope's observations on *Thespesius* and *Ischyrotherium*] Idem, pp. 74–75.

On the enemies of *Difflugia*, and on a supposed compound derived from leather. Idem, p. 75.

Notice of some new fresh-water rhizopods Idem, pp. 77–79.

Notice of some fresh-water and terrestrial rhizopods. Idem, pp. 86–89

Remarks on the revivification of *Rotifer vulgaris*. Idem, pp. 88–89.

On *Pectinatella magnifica*. On a parasitic worm of the house fly, *Filaria muscæ*. Idem, pp. 139–140.

[On fresh-water Infusoria. On a remarkable *Amœba*, its process or mode of swallowing.] Idem, pp. 142–143.

On the motive power of Diatomes. Idem, pp. 143–144.

Remarks on sponges. Idem, pp. 144–145.

Notice of some rhizopods. Idem, pp. 155–157.

Notes on *Dryocampa*. Idem, p 160 (7 lines).

Notice of remains of *Titanotherium*. Idem, pp. 165–166.

On supposed spermaries in *Amœba*. Idem, p. 168.

Notices of rhizopods. Idem, pp. 166–168.

Remarks on fossils presented. Idem, pp. 223–224.

Notices of rhizopods. Idem, pp. 225–227.

1875

On a fungus in a flamingo Proc Acad. Nat. Sci Philadelphia, vol. 27, pp 11–12 (Illustrated)
Notes on some parasitic worms Idem, pp. 14–16 (Illustrated)
Notes on some parasitic worms Idem, pp 17–18.
Remarks on some marine rhizopods. Idem, pp. 73–76 (Illustrated)
Remarks on a coal fossil. Idem, p 120. (Illustrated)
Remarks on elephant remains Idem, p. 121
On a curious rhizopod [on a mouthless fish]. Idem, pp. 124–125
On psorosperms in a mallard duck (on our amœba). Idem, p. 125.
On *Mermis acuminata*. Idem, p 400 (14 lines).
Remarks on rhizopods [On *Quercus heterophylla*] Idem, pp. 413–415
On some parasitic worms American Journ. Sci., 3d ser, vol 9, pp 478–479

1876.

On *Petalodus* Proc. Acad Nat Sci Philadelphia, vol. 28, p. 9
Mastodon andium Idem, p 38 (11 lines)
Remarks on Arcella, etc. Idem, pp. 54–58
Remarks on fossils from Ashley phosphate beds. Idem, pp. 80–81.
Fish remains of the Mesozoic red shales Idem, p 81 (10 lines).
Remarks on vertebrate fossils from the phosphate beds of South Carolina Idem, pp 114–115.
Remarks on the rhizopod genus *Nebela*. Idem, pp 115–119. (Illustrated)
Bituminous sediment of the Schuylkill River Idem, p. 193.
Remarks on the structure of precious opal. Idem, pp. 195–197.
Observations on rhizopods. Idem, pp. 197–199.
On ozocerite hyraceum and itacolumite. Idem, p 325

1877.

[On the contamination of the drinking water.] Proc. Acad Nat Sci. Philadelphia, vol. 29, p 20.
On *Eozoon canadense* Idem, p 20 (10 lines).
On the human diaphragm. Idem, p. 20 (6 lines).
Remarks on the Yellow Ant Idem, p 145
On intestinal parasites of *Termes flavipes* Idem, pp 146–149
Remarks on gregarines. Idem, pp. 196–198.
On *Chilomonas* Idem, p. 198.
On flukes infesting mollusks (*Monostoma lucanica, Distoma ascoidea, Distoma appendiculata.*) Idem, pp. 200–202
Remarks on some parasitic infusoria. Idem, pp. 259–260
Remarks on the seventeen-year locust, the Hessian fly, and a Chelifer. Idem, pp. 260–261
The birth of a rhizopod Idem, pp. 261–265.

On the bed-bug and its allies. Idem, p 284.
On the feeding of dinamœba Idem, pp 288–290
Concretions resembling bones Idem, p. 290
Apparent discriminative power in the selection of food by a heliozoön. Idem, pp 291–292
Remarks on rhizopods, and notice of a new form. Idem, pp. 293–294.
Remarks on ants Idem, pp 304–305.
Remarks on the American species of Difflugia. Idem, pp 306–308.
Circumspection of ants. Idem, p. 320.
Rhizopods in an apple tree. Idem, p. 321
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1878.

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A Hippopotamus tusk Idem, p 99 (7 lines).
On Amœba. Idem, p. 99.
A louse of the pelican. Idem, pp. 100–101
On parasitic worms in the shad (*Filaria capsularia*) Idem, p. 171
Species of *Euglypha, Trinema, Pamphagus*, and *Cyphoderia*, with Synonyma and descriptions of new forms. Idem, pp. 171–173.
Foraminifera of the coast of New Jersey. Idem, p 292 (9 lines)
On black mildew of walls. Idem, p. 331.
Foraminiferous shells of our coast. Idem, p. 336
On crustaceans at Cape May, N. J. Idem, p. 336
Notice of a Tetrarhynchus (*T. tenuicaudatus*). Idem, p 340.
On *Donax fossor*. Idem, pp. 382–383
Notice of gordius in the cockroach and leech. Idem, p 383 (11 lines).
On *Tænia mediocanellata*. Idem, p. 405

1879.

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On *Gordius*, and on some parasites of the rat. Proc. Acad Nat. Sci. Philadelphia, vol. 31, pp. 10–11.
Fossil remains of a caribou. Idem, pp. 32–33.
On *Bothriocephalus latus*, Idem, p. 40.

On Rhizopods occurring in Sphagnum Idem, pp 162–163.
On fossil foot-tracks in the anthracite coal measures. Idem, pp. 164–165.
The explosion of a diamond. Idem, p. 195.
Remarks on orgyia. Idem, pp 195–196.
Notice of some animals on the coast of New Jersey. Idem, pp 198–199.
On *Cristatella idæ*. Idem, pp 203–204.
On *Amœba blattæ* Idem, pp. 204–205.
Ward's Natural Science Establishment Idem, p 208–209.
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1880.

Notice of the cruel thread worm, *Filaria immitis,* of the dog. Proc. Acad. Nat. Sci. Philadelphia, vol 32, pp 10–12.
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Remarks on pond life. Idem, pp. 156–158.
Rhizopods in the mosses of the summit of Roan Mountain, North Carolina. Idem, pp. 333–340.
Bone caves of Pennsylvania. Idem, pp. 346–349
On *Bathygnathus borealis*. Journ. Acad. Nat. Sci. Philadelphia, vol. 8, pp. 449–510.
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1881.

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1882.

Remarks on some rock specimens. Proc. Acad. Nat Sci. Philadelphia, vol 34, pp. 10–12.
Filaria of the black bass. Idem, p. 69.
On Tourmalines. Idem, pp. 71–73.
On *Balanoglossus aurantiacus*, etc. Idem, p. 93 (13 lines).
On *Scolithus* in gravel. Idem, p 93 (13 lines).
On Sagitta, etc. Idem, pp. 102–103
On some entozoa of birds. Idem, p. 109
On coprolite and a pebble resembling an Indian hammer. Idem, pp 109–110.
On *Bacillus anthracis*. Idem, p. 145.
On *Enchytræus, Distichopus,* and their parasites. Idem, pp. 145–148.
The yellow ant with its flocks of aphis and coccus Idem, pp. 148–149.
Colorless garnet and tourmaline. Idem, p 149 (6 lines)
On Balanus, etc., at Bass Rocks, Mass. Idem, pp. 224–225.

On the tobacco worm, etc. Idem, pp. 237–238.
Rotifera without rotary organs. Idem, pp. 243–250.
A new infusorian belonging to the genus *Pyxicola*. Idem, pp. 252–253.
On *Actinosphærium eichhornii* Idem, pp 260–261
On topaz and biotite. Idem, p. 261 (8 lines).
On *Actinosphærium*, etc. Idem, pp. 261–262.
On *Tubularia crocea*. Idem, p. 263 (8 lines).
On remains of horse. Idem, pp. 290–291.
On an extinct peccary (*Platygonus vetus*). Idem, pp 301–302.

1883.

On *Urnatella gracilis*. Proc. Acad. Nat. Sci. Philadelphia, vol. 35, pp. 39–40.
Extinct peccaries of N. A. Idem, pp. 40–44.
[On *Pediculus vestimenti*] Idem, p. 46 (5 lines).
On the reproduction and parasites of *Anodonta fluviatilis* Idem, pp. 44–46.
A flint nodule from greensand of New Jersey. Idem, p 76 (11 lines).
A social heliozoan. Idem, pp. 95–96.
Mineralogical notes. Idem, p 202 (8 lines).
Manayunkia speciosa. Idem, pp 204–212.
On a fungus infesting flies, and remarks on *Manayunkia*. Idem, p. 302.
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1884.

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On cassiterite from Black Hills, Dakota. Idem, vol. 36, p. 9.
[An account of the effects of the storm on marine animals of the New Jersey coast.] Idem, pp. 12–13.
Fossil bones from Louisiana. Idem, p. 22.
Foraminifera in the drift of Minnesota. Idem, pp. 22–23.
Distoma and *Filariæ*. Idem, pp. 47–48.
Dictyophora as *Apsilus vorax* Idem, pp 50–51.
On *Eumeces chalcides*. Idem, p. 66 (8 lines).
Vertebrate fossils from Florida. Idem, pp. 118–119.
A rare human tapeworm [*Tænia flavopunctata*]. Idem, p. 137. See also American Journ Med. Sci., 1884, p. 110.
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1885.

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Rhinoceros and *Hippotherium* from Florida. Idem, pp. 32–33 (Illustrated)

Remarks on *Mylodon* Idem, pp. 49–51 (Illustrated)

Bothriocephalus in a trout. Idem, pp 122–123.

Worms in ice (*Lumbricus glacialis*). Idem, pp 408–409

Extinct hydroid Science, vol. 5, p 395.

A parasitic leech (*Adenobdella oricola*). Idem, pp. 434–435. (Illustrated.)

1886.

Mastodon and llama from Florida. Proc. Acad. Nat. Sci. Philadelphia, vol. 38, pp 11–12.

An extinct boar from Florida. Idem, pp. 37–38.

Caries in the mastodon. Idem, p. 38 (11 lines).

On *Amia* and its probable *Tænia* Idem, pp 62–63

Toxodon and other remains from Nicaragua, C A. Idem, pp 275–277 (Illustrated)

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